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WEEKLY August 29 - September 4, 2015

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CHAOTIC BIRTH**
Our planet nearly
didn't form at all

SYNTHETIC AESTHETICS
The future, designed by biology

NOTHING TO SNIFF AT
Whiffy trick makes
placebos stronger

SPECIAL REPORT The project to put your privacy back in your hands

INTO THE UNKNOWN

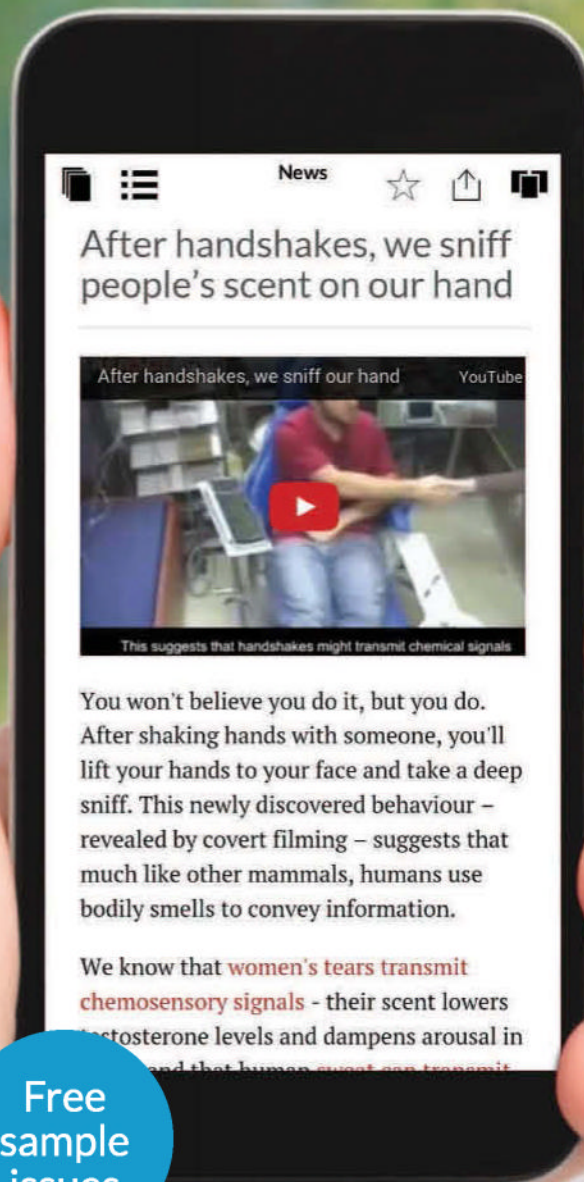
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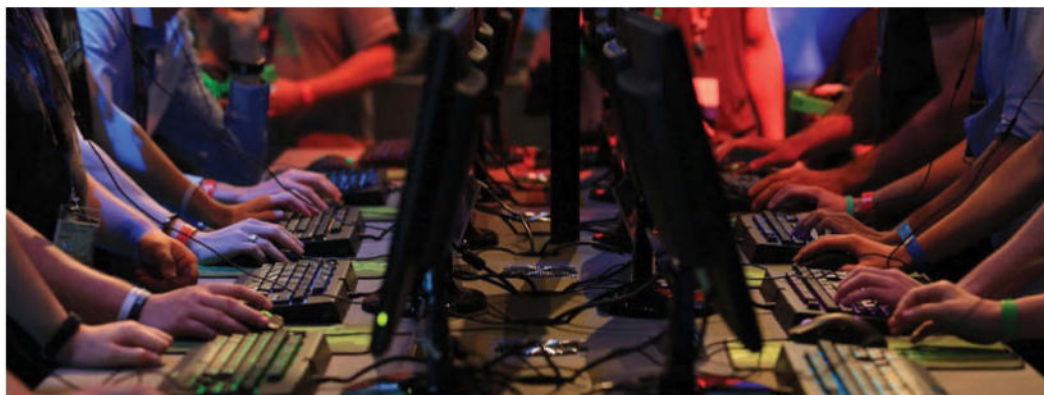
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Take the power back

It is not too late to reclaim our privacy

PRIVACY is dead. So opined many last week, after hackers leaked personal information about some 35 million users of Ashley Madison, a website designed to facilitate extra-marital affairs. Humiliation on a massive scale followed. The fallout – including lawsuits, extortion attempts and, reportedly, suicides – is unlike that of any previous hack.

Don't be distracted by whatever opinions you may have about the morality of the site and its users. The real point is that ordinary people have now become targets of the extreme violations of privacy usually directed at public figures, fuelled by a toxic mix of prurience and schadenfreude – and on unprecedented scales.

How did we get here? Data has become currency: we barter it for services from operating systems to music players, while accepting promises of personalisation and assurances of security from those to whom we entrust it.

That trust is misplaced. Silicon Valley is built on data trading, and its products reflect that. Webmail isn't encrypted; that would stop lucrative ads. Apps don't tell us what they're doing. Ad-trackers stalk you as you browse. And instead of real security, we are exhorted to strengthen our passwords – which is unintuitive and largely futile.

This isn't how things have to be. Researchers are testing systems that would return control over our

data to us (see page 10). Hacking would still be a risk, but there would be fewer enticing targets. Such systems are complex, but so are, say, spam-filtering and online shopping. Given a will to use them, we would find a way.

Does that will exist? Not among the social media titans. Start-ups focused on privacy haven't caught on so far. Perhaps it is more likely to come from a grass-roots effort. That can be effective: ad-blocking extensions for web browsers, built by volunteers, are now used by nearly 200 million people. But if the effort doesn't start soon, vested interests may become too deeply entrenched to overturn. And that really might kill off privacy for good. ■

Not outsmarted yet

ANYTHING you can do, a machine can do better. Well, not really, but that's what it has felt like lately. Rapid advances in "deep learning" have led to computers whose abilities rival or exceed ours, in tasks ranging from describing pictures to driving (page 19).

Cue a wave of anxiety about the potential for automatons to displace us not just on production lines, but also in white-collar and

creative work. Some pundits are even warning that employment as we know it will cease to exist.

Perhaps. Right now, computers are mostly augmenting human smarts – for example, in medical diagnosis (page 18). Or solving problems without being limited by the human mind, allowing them to invent novel gadgets or even push back the frontiers of mathematics (page 28).

Will machines one day supplant thinkers and tinkerers altogether? Even where they outperform us, their discoveries will only be useful if we can make sense of them and apply them.

We already use tools that do things no human could, and whose workings no one person understands. In those respects, "thinking" machines are not so different from, say, the LHC – tools, or perhaps partners. At least until they start to have questions and desires of their own... ■



Tumbling stocks

China crash

IT'S just growing pains. China's stock market plunged dramatically this week, and others around the world fell with it. Aside from stirring memories of 2007, it seemed a bad omen for crucial climate negotiations in Paris in December. China's historic agreement to rein in its greenhouse emissions by 2030 is central to success there, so could financial crisis put its environmental concerns on hold?

On the contrary, the week's events actually reflect what made the 2030 pledge possible. "This round of economic slowdown is part of China's effort to rebalance its economy to a less energy and CO₂ intensive one," says Li Shuo of Greenpeace China.

The country became prosperous, and the world's largest CO₂ source, by investing in manufacturing and power.

But to keep boosting prosperity, China, like all rich countries, must shift to an economy governed by consumer spending, innovation and service industries – which means less CO₂. China's decision in 2013 to make the transition by 2022 led to its emissions pledge in 2014. So that is unlikely to change now, says Li.

In fact, this week's crash was mainly a speculative bubble bursting. But manufacturing, coal and oil were worst hit, while service industries were fine. Rather than climate, it could point to another global problem. More evidence emerged last month that market crashes self-organise when investors overreact, copying each other rather than responding to outside information.

Quantum boost?

AND they're off! Canadian company D-Wave Systems claims that its new quantum computer, the D-Wave 2X, is up to 15 times faster than regular PCs, but some

"Quantum computers promise massive speed-ups, but putting these into practice is tricky"

outside experts say the latest test is not a fair comparison.

Quantum computers promise massive speed-ups over ordinary machines by using qubits, which can be both a 0 and a 1 at the same time. But putting these into practice has proved tricky, and although experiments show that the D-Wave machines display quantum behaviour, it's not clear whether this is responsible for speeding up computation.

D-Wave put the 2X through its paces with a series of benchmark tests based on solving random optimisation problems, and compared the results against specialised optimisation software running on an ordinary PC. The PC

found an answer between two and 15 times slower.

That may not put the 2X ahead, however. The test wasn't looking for the best possible answer. Instead, D-Wave gave its machine 20 microseconds of calculation time to reach some solution, and the regular computers had as long as it took to find a solution of equivalent quality.

Finding the best answer would take much longer. A true comparison should measure the time taken to reach this answer instead, argues Matthias Troyer of ETH Zurich in Switzerland.

Emission-zone fail

BAD news for people with asthma – and London motorists. Attempts to clean up the city's air by charging drivers of polluting vehicles to enter a "low emission zone" didn't get off to a good start.

Launched in 2008, the scheme was projected to deliver drastic reductions in polluting particles. But in its first three years, there was no change in air quality, says Frank Kelly at King's College London.

He and his colleagues also tracked the respiratory health of

pupils at 23 schools in east London, but saw no improvement in their health over that time (*PLoS ONE*, doi.org/63s).

Earlier this year, London's mayor confirmed plans to launch an ultra-low emission zone to enforce stricter pollution standards on vehicles.

Although Kelly approves of stricter measures, he points out that current plans still involve charging the owners of vehicles to drive in the zone. "If you really want to achieve an improvement in air quality, these vehicles should be banned," he says.

US fires rage on

NOT out of the woods yet. Wildfires in the US Pacific Northwest have stayed one step ahead of forecasting models designed to help fight them, because of wind and dry wood. Huge areas are burning in Washington, Oregon and Idaho.

"The weather was the perfectly wrong combination to make this manageable," says Brian Potter of the US Forest Service in Seattle, Washington. "The lightning and



Curse those high winds

wind were so quick on each other's heels that nobody had a chance to put the [fires out] before they got a foothold."

One challenge has been that models of fire behaviour – which firefighters use to allocate resources – aren't as good at predicting where wildfires will move once winds exceed about 25 kilometres per hour.

The weather forecast for the coming week looks calm, which should help but "we're not out of the woods yet", says Potter. "At the end of the forecast there's a chance of lightning, which is just a frightening concept right now."

UFOs attack LHC

ALWAYS expect the unexpected. Physicists at the Large Hadron Collider at CERN near Geneva in Switzerland say that plans to run their experiments at higher energies are likely to be delayed until next year. And it is down to what are playfully known as unidentified falling objects, or UFOs.

The LHC was rebooted in April, after a two-year shutdown to upgrade the machine. In its second run, it will collect data on the highest-energy collisions of particle beams ever. But researchers in charge of getting it up and running again have revealed that things haven't gone quite as planned. This week they presented the first report on the LHC's performance at a conference in Ljubljana, Slovenia.

They say clouds of electrons created by ionised gas in the beam chamber and microscopic dust particles – UFOs – are interrupting the beams and making it harder to get the LHC running consistently.

The team is only a few weeks behind schedule in preparing beams for the experiments. But because the quality of the beam gets better and more stable the longer it runs, there won't be time this year to reach peak performance.

Flu fighters

TIME to turn the tables on flu. The virus fools our bodies into never becoming fully immune – but the search for a universal flu vaccine is a step nearer to success.

The immune system targets proteins on the virus's surface. But the proteins evolve so your body doesn't recognise them in a new strain of flu, hence repeated yearly flu seasons – or worst, occasional lethal pandemics.

But there are other, hidden viral proteins that don't change when the virus evolves because they have precise mechanical jobs to

do. Two research groups have now made stable versions of one such protein. Mice, monkeys (*Science*, doi.org/63w) and ferrets (*Nature Medicine*, doi.org/63v) with immunity to the protein survived widely different forms of flu.

"A universal flu vaccine is a step nearer with the discovery of proteins that don't evolve with the virus"

The vaccine didn't stop flu infection – but stopping people dying might be a good enough reason to stockpile such a vaccine for pandemics.

ISIS shows temple demolition

ANOTHER treasure lost forever? The Islamic State has released images that purportedly show the destruction of Baal Shamin – a temple in the ancient Syrian city of Palmyra, a UNESCO World Heritage site it seized in May.

The temple was one of the city's best-preserved ruins, a 2000-year-old structure originally dedicated to a Canaanite god. "It's a unique example of great age, great integrity, great authenticity," says Brian Daniels of the Penn Cultural Heritage Center at the University of Pennsylvania in Philadelphia. "In 2000 years, the temple has survived not only the ravages of time and decay, but also human conflict and change."

Michael Danti, academic director at the Syrian Heritage Initiative in Boston, expects that ISIS will continue to set the explosives off in the coming weeks, destroying the surviving archaeological features. "It's a form of psychological warfare against the global community. It makes people feel they're powerless to stop it," he says.

His team is working with museums and locals in parts of Syria not controlled by ISIS to help repair combat damage such as lost doors and windows, and restore structural integrity to buildings that are at risk.

"These groups are robbing the future by destroying cultural assets," says Danti. "We're trying to save it."



Gone in 60 seconds

60 SECONDS

Hawking's new idea

Stuff that falls into a black hole is gone forever, right? Not so, said Stephen Hawking this week. Information about particles passing inside could be trapped on a black hole's surface, encoded as a kind of hologram. Photons emitted by the black hole, known as Hawking radiation, could pick up this information and carry it away – but it would be garbled and useless, he said.

Self-aware plants

Plants seem to know themselves and can discriminate between their own "bodies" and those of other plants. The tendrils of the vine *Cayratia japonica* are more likely to coil around neighbouring plants than other parts of its own vine (*Proceedings of the Royal Society B*, DOI: 10.1098/rspb.2015.1379).

Ice sheet breakup

A 12.4-kilometre-square section of ice seems to have broken off the Jakobshavn glacier on the Greenland ice sheet. If so, it could be the largest calving event seen from this sheet. The broken slab would contain enough ice to cover Manhattan in a layer 300 metres deep.

Dementia chances drop

Scare stories tout there's a dementia tsunami on the way, as populations age. But four out of five large studies have now suggested that our chance of getting dementia by any particular age is less than that of previous generations. Better physical health could explain the improvement.

Kiwis cull wrong bird

Oops. Four critically endangered takahē birds were accidentally shot in New Zealand last week. There are thought to be only around 80 or so left in the wild and some 300 in total. The birds were apparently mistaken by hunters for pukekos, which are being culled because they harm endangered birds. The cull has since been stopped.

No place like home - or is there?

Earth is unique but it's not so hard to make a fair copy, finds **Jacob Aron**

YOUR existence is unbelievably unlikely. Think of everything that happened for you to be born: your parents met, a particular sperm fertilised a particular egg, ultimately giving rise to the specific sequence of genes that is you.

But if it hadn't happened that way, someone else would be reading this in your place. We're unique, but that doesn't make us special: there are 7 billion other humans on the planet. Now, thanks to a glut of data on planets in other star systems, astronomers are starting to realise the same is true of Earth itself.

Researchers have discovered nearly 2000 exoplanets so far, the majority found by NASA's Kepler space telescope. Getting a better picture of our galactic neighbours helps put our solar system into context, says Peter Behroozi of the Space Telescope Science Institute in Baltimore, Maryland. "Kepler has been fantastic for setting some of the limits on how many planets are likely to be found around stars, especially for Earth-like planets."

Behroozi and his colleague Molly Peeples have combined the latest exoplanet statistics with our understanding of how galaxies form stars. The result is a formula that tracks the growth in the number of planets in the universe over time (arxiv.org/abs/1508.01202).

It suggests there are currently 10^{20} , or 100 billion billion, Earth-like planets in the universe, with an equivalent number of gas giants. "Earth-like" doesn't mean an exact replica of our planet, but rather a rocky world that, if blanketed by a suitable atmosphere, would hold liquid water on its surface. Applied to the solar system, this definition

would include Mars and Venus but not Mercury or the moon.

And that's just the start. Only a fraction of the gas within all the galaxies in the cosmos has cooled enough to start collapsing, so stars and planets will continue forming for billions of years. That means 92 per cent of the

"Over 90 per cent of Earth-like planets have yet to form, and won't until long after the sun dies"

universe's Earth-like planets won't exist until long after the sun has died and taken the Earth with it.

"Philosophically, if you want to know our place in the universe as a whole, then you also need to

include what will happen in the future," says Behroozi. "I didn't expect to find the Earth had formed so early."

Figuring out where we fit in the grand cosmic timeline also gives us an idea of how many other civilisations might be out there. Suppose intelligent life is so rare that Earth is the first planet in the universe to evolve a civilisation – an almost ludicrously conservative assumption. Then the sheer number of future Earth-like planets means that the likelihood of us being the only civilisation the universe will ever have is at most 8 per cent.

If we find just one other inhabited planet in the Milky Way, the number of other such worlds rockets up. Such a discovery,

together with the unlikeliness of our galaxy being the only one to host life, would make Earth at least the 10 billionth civilisation in the universe at present.

Despite this abundance of other Earths, the odds of there being an exact carbon copy of our world are so low as to be impossible, just as the genetic lottery will never produce your exact twin in another family. But as we are now realising, that's in part due to the precariousness of our existence in the first place.

The basic recipe for a solar system reads: take one giant gas cloud and leave it to collapse under gravity for a good few million years, until it becomes a newborn star surrounded by a spinning disc of leftover gas and



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dust. Wait patiently for another few million years as this clumps up to form planets.

But the details of how this process plays out are still a mystery. One way to study it is through computer simulations of swirling particles. Set them up with different initial conditions, and rate how closely the resulting planets match what we find in our solar system.

It turns out that even near-identical starts lead to different outcomes, as Volker Hoffmann at the University of Zurich, Switzerland, and his colleagues have discovered. They simulated a solar system in the middle of forming, starting with a gas disc containing 2000 planetismals – lumps each around 4 per cent of the moon's mass.

Previous work shows that Jupiter and Saturn formed earlier than the other planets, and that their gravity had a large influence on the rest of the solar system. So Hoffmann's team also simulated

systems with two gas giants in two different types of orbit.

The team ran all three scenarios 12 times with slightly different initial conditions, each simulation requiring a month of computing time. They found that if just one planetesimal was moved by a millimetre, an entirely different set of worlds emerged (arxiv.org/abs/1508.00917).

This was surprising, Hoffmann says, but it makes sense because the planetesimals can interact in many ways, so the situation is inherently chaotic. "It's the same issue that happens in weather and climate modelling," he says. "You change the initial condition a little bit, and the system goes somewhere else."

Gas giant helpers

The consequences are startling. Even smaller changes can probably give rise to the same chaotic effects, says Hoffmann, so adding just one extra molecule to the early solar system could mean the Earth never formed.

But, slightly counter-intuitively, the simulated solar systems end up looking quite similar, the exceptions being the simulations with no gas giants. These end up with around 11 rocky planets, most of which are less than half the mass of Earth.

Stick the gas giants in, and you get around four rocky planets ranging from half an Earth mass to a little more massive than Earth – a pretty good match for our own solar system.

So even if that extra molecule had been floating about, the result wouldn't have looked that different. "Something like Earth would probably have come up, and maybe something alive would have developed," says Hoffmann. "But not us."

Don't let this desolate randomness get you down, says Rebecca Martin of the University of Nevada, Las Vegas. "It's exciting that we're not special," she says, because it means life is abundant



Not quite Earth's twin, but close

NASA/JPL-CALTECH

in the universe and we can go looking for it.

Working with Mario Livio at the Space Telescope Science Institute, Martin has compared data on the known exoplanets, plus likely but unconfirmed candidates seen by Kepler, with planets in our solar system. Their aim was to see if anything stood out as unusual (arxiv.org/abs/1508.00931).

For the most part, ours is a bog-standard system, but a few aspects raise an eyebrow. Mercury is our innermost neighbour, yet it lies beyond the average orbital distance for exoplanets, suggesting our solar system is unusually stretched-out.

Alternatively, that could be down to observational biases. We typically detect exoplanets by the dimming or wobbliness their orbit produces in their star's light,

"Adding even one extra molecule to the early solar system could mean the Earth never formed"

and it is much easier to spot this the closer in a planet is, because we have to wait less time for them to complete an orbit. Recent work also suggests Mercury might be the sole survivor of a pile-up between close-in worlds, which could explain the lack of planets nearer the sun.

Our solar system also lacks super-Earths, objects more massive than Earth but lighter than Uranus or Neptune. They can be rocky or gassy, depending on

their density, and seem to be very common in other star systems. So why don't we have one?

For now it's a mystery, but one possibility is that super-Earths are bad for life. A drifting super-Earth can suck up rocky material that would otherwise form an Earth-like world, leaving behind planets in the star's habitable zone that are roughly Earth-sized but don't look much like our home – they're less rocky and more gassy. If that had happened here, we wouldn't be around to notice, so perhaps our very existence precludes our having a super-Earth for a neighbour.

Taken together, all this research into exoplanets may herald another Copernican-like revolution, as we realise just how mundane Earth is. "Our papers are pointing to the fact that we're really not that special," says Martin. "When you look at the exoplanetary systems you might think we are quite different, but in the grand scheme of things, we're not."

It might seem difficult to accept. But the upside is we're almost certainly not alone – and if we are, that tells us something about the conditions governing the evolution and destruction of life, says Behroozi. "I personally believe that it's very unlikely we are the only ones," he says; aliens must be out there. "Will they wonder this question themselves, about how unique they are?" Maybe one day we'll be able to compare notes. ■



Planet-building is just taking off

Your data, your rules

After Ashley Madison, we need ways to take back control of our data

Sally Adee

ONLINE privacy as you know it died last week. But the reaction to the release of Ashley Madison's dossier of more than 30 million people seeking affairs was one of muted resignation. "Assume everything you do and say will be made public," one commentator declared. Another bemoaned "the impossibility of perfect privacy". The received wisdom is clear: our data will never be safe.

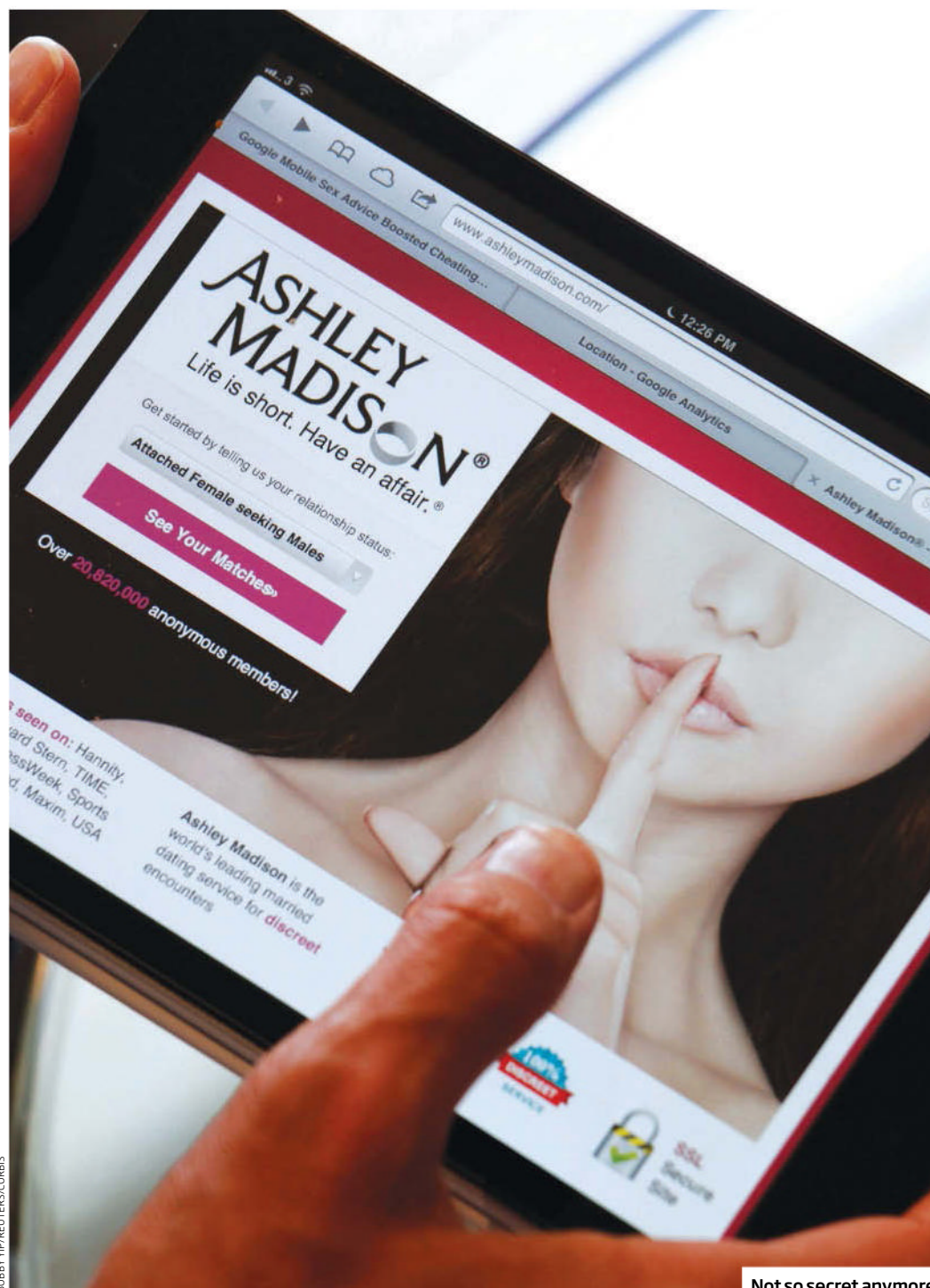
This collective shrug is the result of security fatigue, says privacy researcher Helen Nissenbaum of New York University. The companies who store our data have all the power, but the responsibility for protecting it has been placed on individuals. And we're ill-equipped for the job. If you were using the Ashley Madison site, the strongest password in the world wouldn't have kept your details off the growing number of

"All of us are shedding data with no clue as to how it is being used, abused or protected"

searchable databases now being scoured by suspicious partners and those looking for dirt.

And it's not just members of illicit websites who need to worry. "All of us are shedding data with no clue as to how it is being used, abused, protected – or not," says Nissenbaum. We are simply meant to have faith that the trade-off of our data for what the company offers us is worthwhile, she says.

It is certainly worthwhile for the companies. Sliced and diced and sold to third parties, data can be a bounteous cash cow. What you get out of the deal is less clear. One thing we do know is that the



BOBBY YIP/REUTERS/CORBIS

Not so secret anymore

model of trusting someone else to hold your data has failed.

Some researchers think you should revoke some of that trust. "I can't believe people put their real names, email addresses and credit card details on to a website like that," says Krzysztof Szczypiorski, a security researcher at the Warsaw University of Technology in Poland. He thinks the Ashley Madison hack will be a watershed moment for people's understanding of just how exposed their data is. He says people will start to avail themselves of smarter ways of disguising illicit behaviour. Email accounts under a different name, and prepaid credit cards that can be loaded anonymously, for example, "would have saved a lot of people's marriages", he says.

Question of risk

Instead of people storing and sending unencrypted nude photos, Szczypiorski thinks steganography will become more popular – embedding a nude photo inside an anodyne picture of ducks at a park, say.

But while those options will work for the tech-savvy, Lee Rainie at the Pew Research Center in Washington DC thinks they won't necessarily trickle down to all people. "Even though they are reminded frequently that their data is at risk," he says, "it's pretty clear that many are making only modest changes – if at all."

Sandy Pentland of the Massachusetts Institute of Technology says that putting the onus on individuals is misguided. "It's the data collectors that are the problem," he says. "They have never had any stake in making your data secure."

For Nissenbaum, it's a question of risk. "If a data collector does not provide adequate security, there's a small risk to them and a potentially large benefit."

The spate of recent hacks may be changing that (see "A history of hacks", right). Breaches such as

that affecting Sony's files last year demonstrate that hacks can damage not only the lives of people whose details are stolen, but also the companies deemed liable for the theft.

Sony suffered financially but survived. Ashley Madison may not fare so well. "Under data protection laws, that case will be a slam dunk," says Patrick Rennie, who specialises in data protection at London-based law firm Wiggin. In the past, it has been difficult to prove damages or distress, he says. "That's not going to be a problem here." Class action lawsuits have been filed in the US and Canada.

"A couple more hacks like this and it will start to change the attitude of the data collectors to holding your data – from cash cow to liability," says Pentland.

Over the past year, there has been growing awareness that "breaches are inevitable", according to IT market research company 451 Research. So what will happen when companies lose their appetite for storing data?

Several protocols are in the works that would change the way personal data is stored. Instead of simply throwing up our hands in frustration every time our data is violated, we could revoke access to

it even when it already exists on the open web. It would be the online equivalent of squeezing toothpaste back into the tube.

"In the current model, the data lives someplace and you have to protect it," says Pentland. "If you share it with someone, they can run away with it. You can chase them, but it's pretty hopeless." So he and his colleagues Guy Zyskind

"Enigma would let you reclaim your data - like squeezing toothpaste back into the tube"

and Oz Nathan have developed a protocol called Enigma, based on the blockchain – the secure digital ledger that tracks bitcoins across the internet.

Instead of having all the data in one place, Enigma constructs a "holographic" version that it breaks into many encrypted pieces and stores in far-flung spots. Anyone can use the Enigma protocol, Pentland says, including Netflix, banks and health providers, but you would be the gatekeeper of your data. You would have the power to give permission to third parties to run queries on it, and the power to revoke that at will.

Think of it as a jigsaw puzzle

whose pieces are in hundreds of different places. "No one piece means anything," says Pentland. "If a thief got their hands on most of it, it wouldn't make any sense."

Once you grant access to someone querying your data – say Netflix wanting to check that you are 18 – then and only then do the relevant jigsaw puzzle pieces coagulate to provide the answer before vanishing again.

The system is based on the anti-fraud record securing bitcoins. Anyone who owns bitcoins has an exact copy of the blockchain, making forgeries impossible and removing the need for third parties like PayPal to verify online transactions. Pentland and his colleagues have turned that same public ledger into an access control manager that tracks and verifies your personal data and any queries, permissions and shares.

There are other ideas about how to keep data safe from prying eyes, or from people who don't want to assume the risk of protecting it. Projects are under way at IBM and Microsoft, whose proposals resemble e-wallets that hold your data for queries but never for direct access or storage.

A version of Enigma will be available later this year, and if such services take off, you truly will be responsible for your own data. At that point, the warnings to guard it will make more sense. "You can still do stupid things under Enigma," says Pentland. "You could give permissions to the wrong person." However, without access to the original "hard copy" of your data, he says, it will become impossible for advertisers to use that data without you knowing, or for people to buy it.

Currently, companies that misuse your data can be sued, says Rennie, but you'll never be able to eradicate data breaches. "You can make theft illegal, but that's not going to stop someone pinching a bicycle." Tools like Enigma could be the next best thing. ■

A HISTORY OF HACKS

NSA - June 2013

Edward Snowden reveals how the US National Security Agency can monitor people's personal data - including medical records, email, bank accounts and phone calls.

Target - November 2013

Malware in the payment system of US retailer Target siphons credit card information, addresses and names of more than 100 million people.

US Homeland Security - March 2014

Social security numbers, financial histories and children's names are leaked when the files of 4 million government employees are exposed.

Officials are warned that the hackers will target the victims for blackmail.

iCloud photo leaks - August 2014

Celebrities' nude photos are swiped from iCloud's online storage platform.

Sony - November 2014

Five Sony Entertainment films are leaked and thousands of internal documents published. The data included private email messages.

Ashley Madison - August 2015

The details of more than 30 million people who signed up to the adultery website are released. The hack has been implicated in two suicides.

North pole, south pole, wormhole

IT'S a new magician's trick, sawing a magnetic field in half – and all you need is a wormhole, and one has been built in the lab for the first time.

This wormhole is no space-time portal, but it allows a magnetic field to disappear and re-emerge elsewhere.

In earlier work, Alvaro Sanchez at the Autonomous University of Barcelona, Spain, and his colleagues transferred a magnetic field across space with a superconducting “hose”. But external fields can distort those inside the hose, so to look like a worm hole the hose has to be invisible to other probing fields.

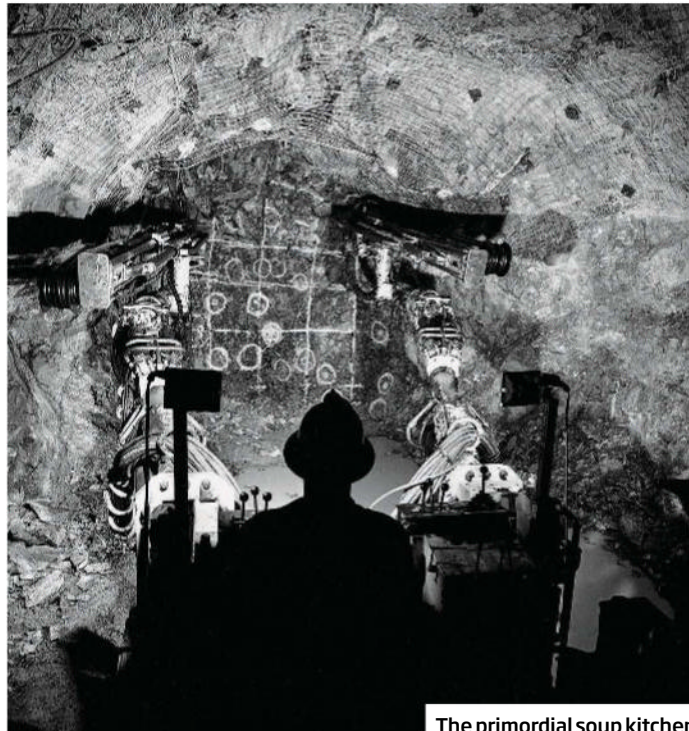
“We needed to make a 3D magnetic cloak to hide the magnetic hose,” Sanchez says. For that they used “metamaterials”, which interact in unusual ways with electromagnetic fields and one day may make invisibility cloaks for light.

The team nested the hose inside a sphere of superconducting strips to deflect incoming fields. But that deflection would be detectable, so they put a magnetic sphere inside the strips to hide the superconductors – the fields cancelled each other out (*Scientific Reports*, doi.org/6z4).

“The whole object is magnetically invisible because of this cancellation,” Sanchez says. When the field pops out the other end, it looks like a magnetic monopole – a lone north or south pole, which hasn't been seen in nature.

Such a wormhole could help cloak MRI scanners from other magnetic fields, Sanchez adds. Multiple MRIs would then be able to work together without interference, or allow distance between bulky sensors and patients – all without changing the magnetic field that MRIs rely on.

The magnetic wormhole is an impressive demonstration of the power of metamaterials, says Matti Lassas at the Helsinki University of Technology in Finland. “It makes the scientific work on invisibility cloaking a step – or in fact, a leap – closer to real life applications.” Joshua Sokol ■



The primordial soup kitchen

Life's roots seen in liquid time capsule

Colin Barras

IT HAS all the ingredients of the primordial soup. Yet biological processes appear to have played no part in forming the life-friendly chemicals discovered in a pocket of water that last saw the light of day 1.5 billion years ago. That lends weight to the idea that reactions around deep-sea vents were what kick-started life.

Barbara Sherwood Lollar at the University of Toronto in Canada and her team discovered the water a few years ago, oozing out of the rocky walls deep in the Kidd mine near Timmins in Ontario.

Chemical analysis suggested that the water had been sealed away inside a cavity in the rock. The water appears to contain no life – making it an extremely rare find.

Originally the rocks formed

part of the sea floor in an area rich in hydrothermal vents. Because the water they contain seems to have been trapped since that time, it could reveal details of the chemistry that might have taken place at such vents before life began exerting its influence.

In theory, hot, chemical-laced water gushing from deep-sea hydrothermal vents would provide ideal conditions for the origin of life. But testing the idea by studying hydrothermal vents today is difficult. “The chemistry is often heavily overprinted by life,” Sherwood Lollar says, making it hard to tell whether compounds we detect there formed before life emerged.

Her team had previously found a wealth of complex organic molecules in the water. Now calculations by Christopher Glein, also at the University of Toronto,

show that these molecules could have formed through perfectly feasible non-biological reactions in the vents.

According to Glein, conditions were particularly favourable for the formation of key chemicals like glyceraldehyde, one of the precursors of RNA and DNA, and pyruvate, which is important for cell metabolism.

Biochemists consider these molecules relatively hard to make without the involvement of life, says Glein, who presented the work last week at the Goldschmidt

“While not the first prebiotic soup, the water pocket is a variety that could give new clues to the origin of life”

conference in Prague, the Czech Republic. “But that’s assuming they are being synthesised under familiar conditions at Earth’s surface,” he says.

Conditions would have been very different in the ancient hydrothermal vents, where the water reacted with the rock through a process called serpentinisation.

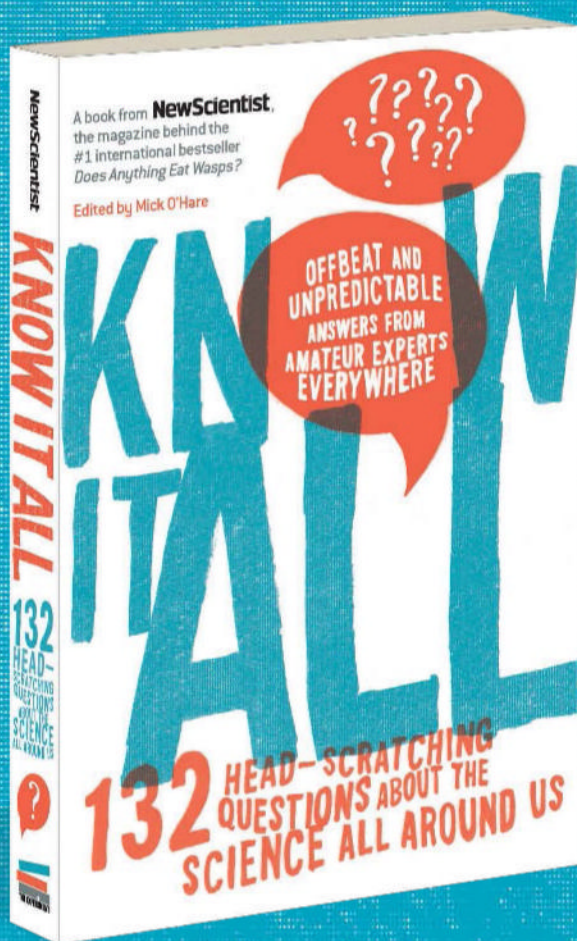
That created an environment poor in oxygen, but rich in hydrogen, iron and sulphur. With temperatures at about 100 °C, many complex organic compounds would have spontaneously formed.

William Martin at the University of Düsseldorf, Germany, says the vents would have allowed much more complex structures to arise. “Hydrocarbon synthesis at serpentinising systems is enough to make even the first membranes,” he says.

Glein emphasises that the water pockets in the Kidd mine, although ancient, are not as old as life on Earth. “We’re not claiming that Kidd actually contains the original prebiotic soup, or a second origin of life,” he says.

“But while not the first brand of prebiotic soup, it’s a variety that can potentially provide new clues about the origin of life.” ■

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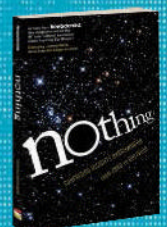
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Trust hormones aid placebo effect

Jessica Hamzelou

SOMETIMES a sugar pill can be all you need to feel better, even when you know it doesn't contain any medicine. We're still not entirely sure why the placebo effect works – but hormones that make us bond with our doctor appear to boost it.

Evidence that a compassionate, trustworthy carer can speed up someone's recovery suggests that there is a social dimension to the placebo effect. And last year, researchers carrying out an all-male trial found that oxytocin – the so-called “cuddle chemical” thought to help us trust others and form relationships – seems to enhance the effect.

Luana Colloca at the University of Maryland in Baltimore wondered if another hormone known to affect social interactions, vasopressin, might have a similar effect.

To investigate, she gave 109 women and men electric shocks to their fingers. The intensity of the shock was tailored to each individual so that they all reported the same, moderate level of pain. The participants

were asked to take a sniff of either vasopressin, oxytocin, salt water, or nothing at all.

Next Colloca told them that each time they saw a green light, the electric shock would be reduced, but that it would remain at the same level if a red light

was displayed. In reality, the intensity never changed. The team compared the pain ratings of the volunteers when they were shown a red light to their scores when they saw a green light. Any difference represents a placebo effect.

Everyone experienced the placebo effect, but it was most pronounced among women given vasopressin (*Biological Psychiatry*, doi.org/6zq).

This makes sense, says Colloca.

Previous research suggests that vasopressin promotes aggression and rivalry between men, but encourages “tend-and-befriend” tendencies among women. Colloca thinks the vasopressin made the women feel more at ease, more cooperative and more trusting when she carried out the experiments.

“It is remarkable,” says René Hurlmann at the University of Bonn in Germany. He thinks that such naturally produced hormones may be responsible for the placebo effects seen in some clinical trials. In future, we may be able to block the effects of hormones in trials, or at least factor them in, to stop the potential skewing of results.

As drugs, the hormones could be used to enhance the effects of other medicines. For example, Colloca hopes the hormones can be applied in treatments for chronic pain. “We know the best care providers interact well with their patients,” she says. “It might be possible to help a person control their pain by enhancing this cooperation response.”

But Tor Wager at the University of Colorado at Boulder thinks it might be easier to improve the environment in which a person receives treatment. “We like to think that a drug does one thing, but the context in which it is given can modify its effects,” he says. ■



MEDICIMAGE/GETTY

Fast track to trust

Octopuses seen firing shells at each other

OCTOPUSES have been recorded gathering up armfuls of debris before taking potshots at one another. Whether it's a case of “get off my turf” or merely “oops, didn't mean to hit you” is still a puzzle.

Octopuses have siphons on the side of their body. They normally expel water through these to propel themselves along. However, gloomy octopuses (*Octopus tetricus*) living on

a bed of shells at Jervis Bay off the coast of New South Wales, Australia, seem to have co-opted this system to throw things at each other. This may be the first use of projectile weapons seen in octopuses.

“Very few animals have been reported to throw things at one another, so it would be significant if the octopuses are doing it,” says Peter Godfrey-Smith, a marine biologist at the Graduate Center, City University of New York, who this month presented video evidence at the Behaviour2015 conference in Cairns, Australia.

“It gathers up a pile of stuff in its arms, and then directs the jet under

the web of its arms, and throws out all the stuff under pressure,” says Godfrey-Smith. He is not yet certain that the behaviour is intentional. It may just be a case of enthusiastic housekeeping showering the neighbours with debris.

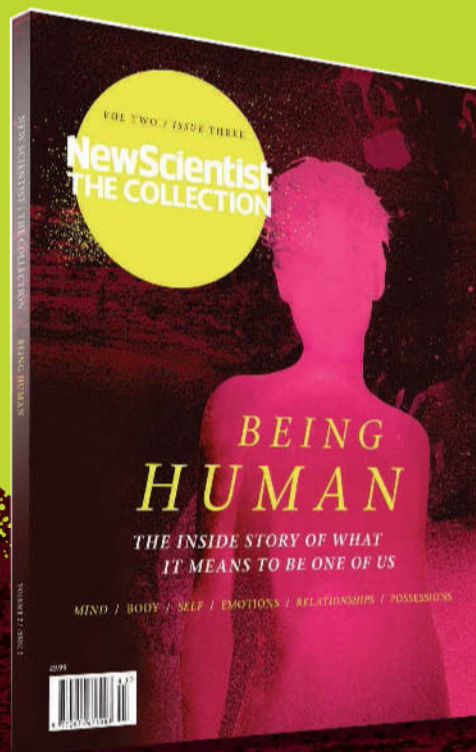
“Octopuses often clean out their homes with a jet of water, pushing out sand and rubble. They also jet at intruders like pesky fishes,” says Jennifer Mather at the University of

“Gloomy octopuses gather up a pile of debris in their arms, then throw it at their neighbours”

Lethbridge in Alberta, Canada, who was not involved in the study.

However, other octopuses got hit by the debris more often than you would expect by chance.

If it is intentional, it may have evolved in response to unusually crowded conditions at Jervis Bay, where octopuses have also been seen to fight, bully and even box with each other (*Marine and Freshwater Behaviour and Physiology*, doi.org/63b). The overabundance of food and a lack of other suitable nesting sites may be why these solitary creatures put up with such a rowdy crowd. Sandhya Sekar ■



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Dainty step gives mosquitoes strength to walk on water

IT'S not a divine power. Mosquitoes can walk on water because of the angle at which their legs touch its surface.

A mosquito's leg is strong enough to bear up to 23 times its total body weight, which is one reason why it can walk on water so effortlessly. This greatly exceeds the leg strength of other water-walking insects like water striders, whose legs have been more rigorously studied.

Jian-Lin Liu of the China University of Petroleum in Qingdao and his colleagues thought a mosquito's advantage might also come from the protective wax and microscopic scales coating its legs. They removed these

layers and measured the change in the leg's load-bearing capacity, but found that the layers were responsible for less than 12.5 per cent of the overall supporting force.

The main player turned out to be the angle between the leg and the water surface. The supporting force was strongest when the leg was nearly parallel to the surface. Any angle greater than 62 degrees would make the mosquito penetrate the surface.

The researchers believe that mosquitoes can adjust this angle during landing and take-off to ensure they remain on the water's surface (*Acta Mechanica Sinica*, doi.org/6zd). This ability is crucial because many species land on fresh or stagnant water to lay their eggs in it.

The work could inspire insect-like robots and waterproof materials, the team says.

Harp with a heart of glass

A POPULAR party trick just got turned inside out. Fill a row of wine glasses with water to different levels, rub your finger around the rim and – hey presto! – you have a glass harp. Now it seems an empty wine glass submerged in liquid plays just as well.

The pitch, or frequency, at which the glass resonates depends on how much the liquid inside pushes back as you play. Daniel

Quinn of Stanford University, California, and Brian Rosenberg, then a grad student at Princeton, realised that this should work when the liquid pushes into the glass from outside as well.

The pair found that the ordinary glass harp and the “inverted” glass harp were the same, mathematically. “That’s one of the things we were surprised about,” Quinn says. “One is really

just a mirror image of the other.”

A single wine glass in a tub of water makes an eerie, theremin-like sound, and the pitch changes as the glass moves up and down.

“You can control the depth yourself, so you only need one glass to perform a variety of pitches,” Quinn says. It was easy to play, too – after just a few minutes’ practice they could play the children’s song *Mary Had a Little Lamb* (*Physical Review E*, doi.org/6zv).

Sick ants’ healthy appetite for a toxin

ANT, heal thyself. That’s no problem for one ant species, which can self-medicate on poisonous hydrogen peroxide.

Colonies of social insects like ants and bees are vulnerable to disease. One way to manage this is to ingest otherwise harmful substances to fight infection, but clear evidence of such behaviour in insects was hard to find.

Nick Bos and his colleagues at the University of Helsinki, Finland, have now shown that *Formica fusca* ants choose to eat hydrogen peroxide if they have a certain fungal disease. Infected ants had better survival odds if fed a diet spiked with hydrogen peroxide.

The same diet raised mortality rates in healthy ants and, when offered the choice, they tended to avoid the spiked food. Crucially, however, the infected ants ate more of it, suggesting they somehow felt that it would benefit them (*Evolution*, doi.org/6zx).

Bed-wetting dries up with magnets

FROM brain to bladder. Magnetic stimulation, a technique usually associated with the brain, has been applied to the lower back to reduce bed-wetting.

A paddle generating a magnetic field was held for 7 minutes a day over the backs of 22 people aged between 10 and 25 years. A further 22 got a sham treatment. Both groups had been wetting the bed six times a week on average.

In the first 10 days, bed-wetting fell to once week for everyone. This was still the case a month later for the first group. The rest went back to their previous behaviour. Co-author Eman Khedr at Assiut University Hospital, Egypt, says the technique may alter nerve function (*Restorative Neurology and Neuroscience*, doi.org/628).

Secret of raptors' daredevil dives

TWO soaring raptors lock talons and suddenly plummet, spinning as they fall. Sometimes they release their grip. Other times they hold on as if in a dare – even to the point of both crashing to the ground.

Known as cartwheeling, this behaviour is hard to witness and harder still to interpret. “If you’re in the field for 100 hours, these events happen within fractions of a minute,” says Jaime Jimenez of the University of North Texas in Denton.

We thought cartwheeling was a dance between lovers, but fresh evidence suggests it is mainly an aerial duel. Jimenez’s team studied reports of 32 cartwheeling flights involving 12 raptor species in Chile, and found most were heated confrontations – even involving different species (*The Wilson Journal of Ornithology*, doi.org/6z6).

“Evolutionarily and behaviourally, they’re very critical for individuals and populations to maintain their territories,” says Jimenez. But when two species were involved, the behaviour was more often the result of attempts to steal from fresh kills.

Gruesome outcomes are known, but cartwheeling doesn’t usually end in disaster. “They use these weapons, the talons, which are very sharp and dangerous, to threaten,” says Jimenez. “I’m here, I’m strong, and I can kill you, but I am not going to kill you.”



Lose weight at the flick of a genetic switch

NOT all fat is created equal – and now we know why. Geneticists have found the gene that orders fat cells to burn rather than store energy. Tinkering with it stopped mice gaining weight.

“You could say we’ve found fat cells’ radiator, and how to turn it up or down,” says Manolis Kellis at the Massachusetts Institute of Technology.

Our bodies contain large deposits of energy-storing white fat and small pockets of calorie-burning brown fat. Beige fat is somewhere in between. It is

dispersed among white fat cells, but burns calories like brown fat.

Now Kellis’s team has found that the gene *FTO* effectively turns white fat into beige.

Kellis and his colleagues looked at the genetic profiles of fat cells from 100 people. About half had an *FTO* variant known to raise the risk of obesity by around 30 per cent. In cells taken from these people, the team found that *FTO* activates two other genes – called *IRX3* and *IRX5* – which direct the cell to store energy. In cells from people with the typical variant,

the same genes are switched off, causing the cells to burn energy.

Kellis’s team was able to use gene editing to adjust the activity of *FTO*, making fat-storing cells burn energy (*New England Journal of Medicine*, doi.org/6z5). Mice with edited genes fed a high-fat diet resisted piling on the pounds.

Kellis thinks drugs or treatments could now be devised that interfere with *FTO* to combat obesity. “We can intervene using this circuitry whether or not you have the genetic risk variant,” he says.

Aspirin restores equal sex ratios

CAN aspirin make some women more likely than they were to have a boy? A study in women who have had one or two miscarriages hints at a link.

On average, a baby is slightly more likely to be born male. But in recent decades, the bias has fallen slightly in Japan, the US and some of Europe. One hypothesis is that modern life makes women more likely to have inflammation, which may lower the chance of male embryos surviving.

Enrique Schisterman of the Eunice Kennedy Shriver National Institute of Child Health and Human Development in Bethesda, Maryland, wondered whether anti-inflammatories like aspirin could change this. Initial results in women who had had one or two miscarriages hint it could be so. Those with high levels of inflammation who took low doses of aspirin had a “normal” 52 per cent chance of giving birth to a boy – for those given a placebo it was 35 per cent (*The Journal of Clinical Investigation*, doi.org/6zb).

However, Schisterman strongly advises women against self-medication with aspirin for this purpose, because there may be risks.



CHRISTOPHE BOISVIEUX/CORBIS

Glacier silicon feeds ocean plankton

FROM icy water comes life. The meltwater beneath Greenland’s glaciers is an important source of the silicon that some plankton need to build their glassy skeletons – and climate change could alter the input.

Glacial meltwater is rich in silicon because the ice pulverises rocks as it passes over them. “Our estimates indicate that the ice sheets could be a huge source of silicon to the polar regions,” says Jon Hawkings of the University of Bristol, UK, who presented his team’s findings at the Goldschmidt conference in Prague, Czech Republic, last week.

The silicon is taken up by plankton called diatoms as they grow. These organisms also photosynthesise, using up huge amounts of atmospheric carbon dioxide in the process. When they die, they sink to the bottom of the ocean, forming a natural carbon sink.

The worry is that with climate change affecting glacier melting, this process could change in unpredictable ways that have knock-on effects on climate change itself. “We believe it is highly likely these inputs will change in a warming climate,” says Hawkings.



Open to misinterpretation

Deeply healthy

Software that can analyse medical data and diagnose diseases is coming. Could it do better than a doctor, asks **Hal Hodson**

IT'S a case of diagnosis without doctors. Software could soon be working out what's wrong with you based only on medical data.

Machines have already transformed healthcare. MRI scanners can peer inside the body, for example, and blood samples are analysed automatically, but human skill has always been an integral part of the process: a scan reveals a shadow – the oncologist recognises its significance. But doctors are often busy and overworked; they can make mistakes or overlook telltale symptoms. If computers could understand health on their own terms, perhaps they could speed up diagnosis and even make it more accurate.

Central to the new approach are advances in machine learning – the way software can be trained to recognise important features in an image, for example.

It's a powerful tool, but generally the software requires a lot of virtual hand-holding: images might have to be carefully aligned, and human experts are needed to make sure the software is trained to recognise the right features.

Deep learning is more flexible. Here, the software works at multiple levels simultaneously. Given a simple image, the computer might process the edges and lines while also considering what the image as a whole portrays – “dog” or “cat”, say. The approach means deep learning can make inferences about sets of data containing quite different concepts without human guidance.

This could be a game-changer for medicine, says Andrew Bradley at the University of Queensland in Australia. “[It can] readily combine images obtained from multiple views

and multiple modalities,” he says.

Take breast cancer detection. Diagnosis potentially requires information from three sources: an X-ray, an MRI scan and ultrasound – and cross-referencing is laborious and time-consuming. Not with deep learning. Bradley and colleagues have a prototype system that cross-references automatically.

“Deep learning software automatically cross-references information from several sources”

They will present it in October at the International Conference on Medical Image Computing and Computer Assisted Intervention in Munich, Germany.

Researchers at Tel Aviv University in Israel have been using deep learning to analyse chest X-rays. So far, their system

can distinguish between enlarged hearts and fluid build-up around the lungs.

Meanwhile, a group at the National Institutes of Health Clinical Center in Bethesda, Maryland, is using similar methods to detect cancerous growths on the spine. Both groups are getting results that equal or better existing state-of-the-art detection algorithms.

But will doctors – or patients – ever accept the word of a machine? That remains a problem, says Bradley. Deep learning's complex networks are inscrutable, spitting out conclusions without giving reasons.

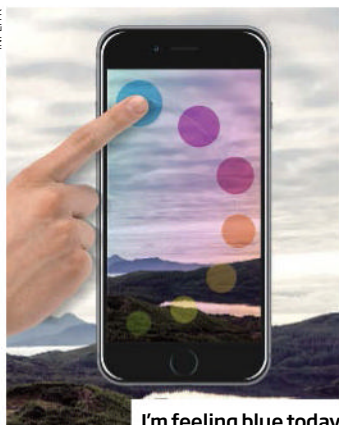
For instance, if you have ever had Facebook suggest you tag someone you don't know as one of your friends, not even a Facebook engineer could tell you why that happened. Apply that level of mystery to medicine and, understandably, people may well get uneasy.

“Give them a black box? The clinicians are never going to embrace that,” Bradley says. That's why he has a second system. Once the deep neural network is trained, Bradley uses its outputs to train another, transparent model – a “white box” whose answers humans can inspect and understand, and which will fail in certain circumstances. “In traditional systems the expert will build in sanity checks,” he says. “Is the thing the right size, colour, place? If not then don't go further.”

We can expect deep learning to have an impact on medicine, says Brendan Fray at the University of Toronto, Canada, particularly with the rise of personalised healthcare and the focus on genes. His startup, Deep Genomics, is bringing the approach to genetic analysis.

“Deep learning will transform personalised medicine, genetic testing and pharmaceutical development,” he says. “It provides the glue between data and medical outcomes.” ■

INFILTR



I'm feeling blue today

Swipe for 5 million filters to spice up your selfies

FEEL limited by Instagram's 30 filters? Try 5 million. A new app for iPhones called Infiltr taps into a smartphone's graphics processor (GPU) to generate filters on the fly, allowing for the perfect shot in one step.

It's the idea of London-based software developer Philippe Leveux, who realised that he could harness a smartphone's processing power to create live filters. He and colleagues use the GPU to change the colour of every pixel on screen in real time, as you are taking the shot, relying on techniques from game development to create Infiltr's 5,120,000 filters.

Choosing one filter from 5 million with an interface like Instagram's would be near impossible, so Leveux and Tamara Sword and Nick Pelling tried another way. Each filter is mapped to a point on the screen. That allows you to swipe around to quickly choose the best one as you frame the picture, with the image changing accordingly.

This may allow "filter" to join "focus" and "exposure" as fundamental photography terms, but only if Infiltr is easy to use. "It is hard to predict the cultural demand for such an approach," says Dan Raviv of the camera culture unit at MIT in Boston. "But this app will be a success if that swipe-based user interface makes the process of choosing the filters enjoyable and not burdensome." Paul Marks ■

Get off the road, human!

Autonomous cars are learning to deal with our unpredictability

IN THE near future, you may have to share the road with a robot. Or perhaps we should say that a robot will have to share the road with you.

At the University of California, Berkeley, engineers are preparing autonomous cars to predict what we impulsive, unreliable humans might do next. A team led by Katherine Driggs-Campbell has developed an algorithm that can guess with up to 92 per cent accuracy whether a human driver will make a lane change. She is due to present the work next month at the Intelligent Transportation Systems conference in Las Palmas de Gran Canaria, Spain.

Enthusiasts are excited that self-driving vehicles could lead to fewer crashes and less traffic. But people aren't accustomed to driving alongside machines, says Driggs-Campbell. When we drive, we watch for little signs from other cars to indicate whether they might turn or change lanes or slow down. A robot might not have any of the same tics, and that could throw us off.

"There's going to be a transition phase," she says. "How do you ensure the autonomous vehicle is clearly communicating with the humans, and how do you know the human is understanding what they're doing?"

Past algorithms have tried to predict what a human driver will do next by keeping tabs on body movements. If someone seems to be looking over their shoulder a lot, say, that might be a sign that they're thinking of moving lane.

Driggs-Campbell and her colleagues wanted to see if they could forecast a driver's actions by monitoring only outside the car.

To see how human drivers do this, they asked volunteers to drive in a simulator. Each time

the driver decided to make a lane change, they pushed a button on the steering wheel before doing so. The researchers could then analyse data from the simulator for patterns at the time of lane changes: Where were all of the cars on the road?

"A robot might not have any of the same driving tics as us, and that could throw us off"

How fast was each one going, and had it recently moved or slowed down? Was there sufficient room next to the drivers' car?

They used some of the data to train the algorithm, then put the

computer behind the wheel in re-runs of the simulations. The algorithm could predict accurately when the driver would attempt a lane change.

Such algorithms would help a self-driving car make smarter decisions in the moment. They could also be used to teach the cars to mimic human driving tics, says Driggs-Campbell.

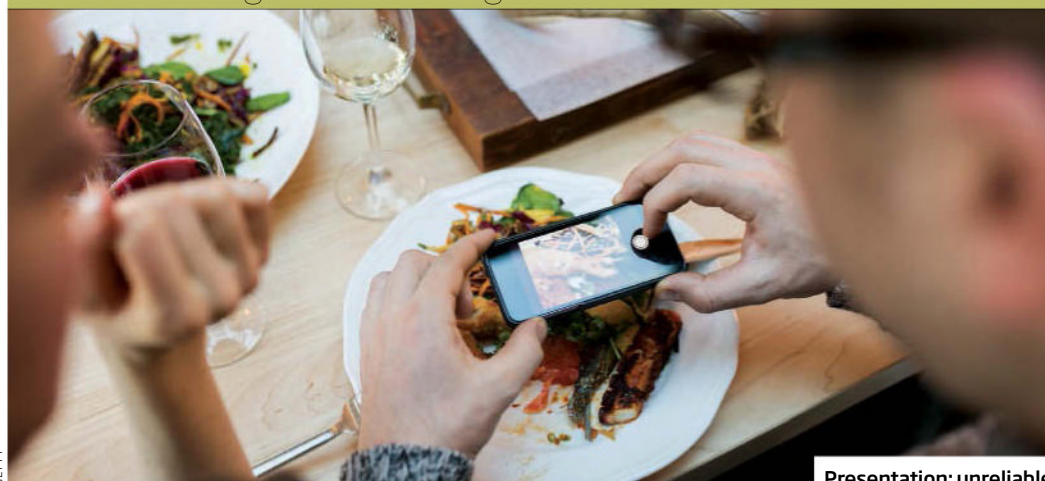
It's good work, but teaching a car to understand others is only the beginning, says Raúl Rojas at the Free University of Berlin in Germany. "Humans are very creative about breaking the rules," Rojas says. "Computers are programmed to never break the rules." Aviva Rutkin ■

MARTIN ROEMERS/PANOS



Mind the dangerously good driver

INSIGHT User-generated ratings



Presentation: unreliable

Serving up trust

How can we clean up the world of online reviews, asks **Aviva Rutkin**

THE internet runs on opinions. If you want to eat out, visit a faraway city or just get a new toothbrush, there are thousands of online reviews to help you make choices. Services like Yelp, Airbnb and Amazon rely on this electronic word of mouth to keep users coming back.

But savvy consumers know that user-generated reviews aren't guaranteed to be credible. Bad comments about a hotel might have been penned by someone with an axe to grind; a rave restaurant review could be by the chef's mother. That's led some tech companies to ask: how can we make online opinions more reliable?

"The main goal of review platforms is to maintain the trust of their users," says Georgios Zervas at Boston University, who studies internet marketing. "If I read some reviews on Yelp that were positive, then I go into that restaurant and have a bad experience, that might make me not trust Yelp reviewers any more."

Fake reviews are part of the problem. Zervas found that at least 16 per cent of reviews on Yelp are flagged by the company's secret algorithm as suspicious, and ultimately filtered out.

Yelp has conducted sting operations, catching out firms offering to pay people to write favourable restaurant reviews. Offenders' listings were temporarily plastered with a banner to warn users as well as businesses that might be considering the same tactic.

In 2013, New York state conducted its own investigation, Operation Clean Turf, into fraud on ratings websites. It involved staff from the attorney general's office calling up local search engine optimisation specialists,

"If I read some positive reviews then have a bad experience, I might not trust the reviewers again"

pretending to be the owners of a yogurt shop desperate for positive press. In the end, 19 companies were penalised for violating laws against false advertising and deceptive business practices.

A different problem surrounds genuine reviews, namely that users might not think them trustworthy. That is now being tackled by a team of researchers at Google, who asked nearly 2000 people to assess the credibility of online restaurant reviews.

Their findings, to be presented next month at the International Conference on Human-Computer Interaction in Bamberg, Germany, suggest that reviews with a balanced tone tend to be trusted. The team says that review platforms might benefit from software that assesses the tone of a review in real time, and tries to nudge reviewers gently away from writing something overly critical or gushing.

When it comes to the presentation of reviews, there might be merits to keeping things simple. Paolo Parigi at Stanford University, California, is studying how trust develops between people who offer accommodation on sites like CouchSurfing and Airbnb, and their customers. He thinks that slick-looking reviews can actually weaken that trust.

Parigi looked at CouchSurfing before and after it added a rating system to its reviewing tools. He found that ratings seemed to make users more selective in choosing who to stay with. What's more, although reviews helped them find an accommodation owner they trusted, users were less likely to form a strong friendship with them when additional details – such as ratings – were available. ■

Power from within

Tap into your personal power supply. Scientists at Sungkyunkwan University in South Korea have built a device from thin layers of metal that harvests energy from inside the body. The researchers have tested the device by implanting it in a rat. As the rat breathed, the patch generated 3.73 volts – about enough to run a pacemaker if it was implanted in a human.

35

The number of days Google has to comply with an order to remove links to news stories that are about other links it has already removed

Gandalf bot

Even robots need support sometimes. Enter the "smart staff", a walking stick designed to help humanoid bots tackle tough terrain. Built by engineers at Stanford University in California, its sensors let robots explore the slope and slipperiness of unfamiliar surfaces. The staff has been tested with a robotic arm and will be presented next month at the International Conference on Intelligent Robots and Systems in Hamburg, Germany.



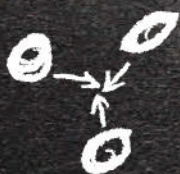
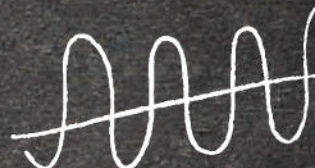
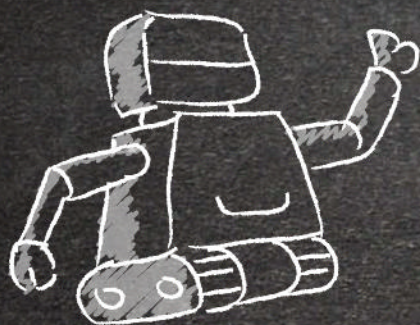
OLUSSANA KHATIB, SHUYUN CHUNG, STANFORD UNIVERSITY

A career in science, it's not always what you think

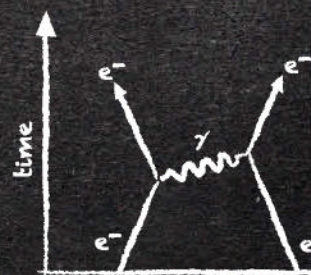
From movie advisor to science
festival director, where will your
science career take you?

NewScientist Jobs

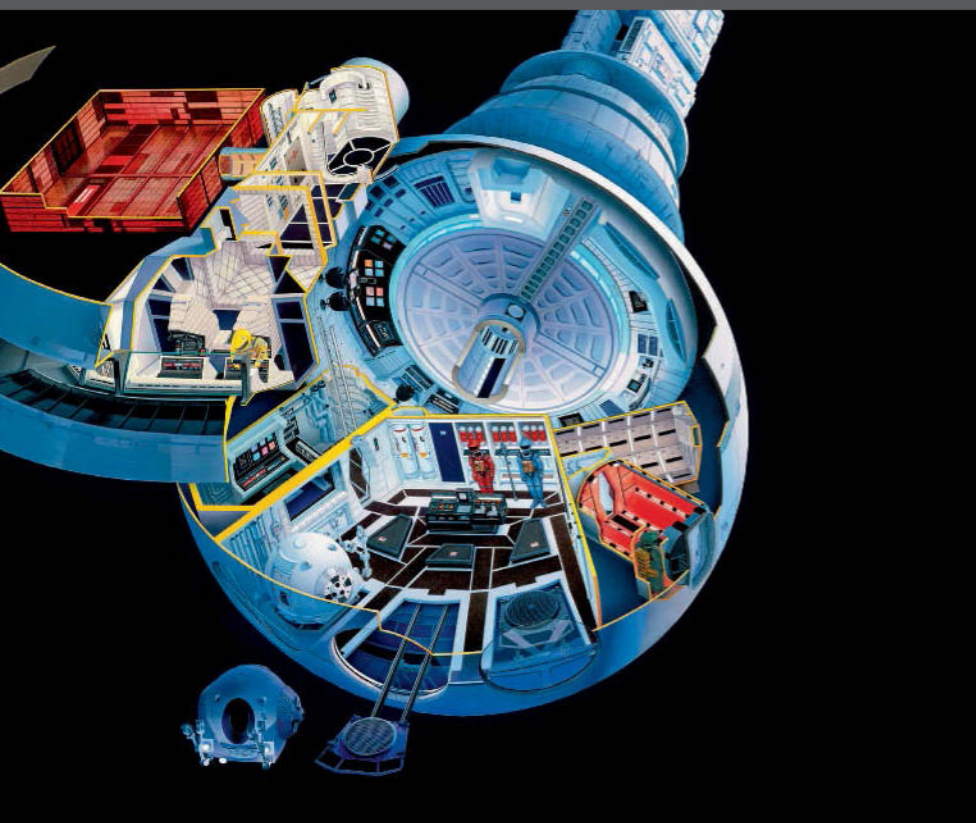
newscientist.com/jobs



$$DR_{ADC} = 20 \times 10^4$$
$$= (6.02 \times 10^{23})$$







How the future was won

HALF a century ago, Stanley Kubrick wrote to Arthur C. Clarke about a movie idea. Clarke was enthusiastic: "The 'really good' science-fiction movie is a great many years overdue." So began their collaboration on *Journey Beyond the Stars*.

The film acquired several nicknames ("How the Solar System was Won" was a favourite), before its release in 1968 as *2001: A Space Odyssey*. As a vision of the future it stands the test of time: a tribute to a writer who dreamed up communications satellites long before a satellite was launched, and a director who, even as Sputnik circled the Earth, was working through reels of Japanese sci-fi to find the effects he would need to imagine his way into space.

Clockwise from top left: the faux-luxurious bedroom in which the final scenes were shot. This comfortable "cage" constructed by aliens got uncomfortably hot, thanks to the underfloor lighting.

A painting by Oliver Rennert shows how the various interiors would fit into the habitation sphere of the Jupiter-bound Discovery.

Data and communications technologies were the most difficult to cast into the future. But this briefcase, designed by the Honeywell company, is essentially a modern laptop, complete with camera, stylus and modem.

Kubrick's special effects are legendary but would have fallen short had it not been for some subtle yet very physical performances, including that of Kier Dullea, here miming weightlessness.

A typically scruffy Kubrick (right) and dapper Clarke pose for publicity photographs on the passenger deck of the Aries lunar ferry.

These and other images are collected in *The Making of Stanley Kubrick's 2001: A Space Odyssey*. All together now: "I'm sorry Dave, I'm afraid I can't do that." Simon Ings

Source

The Making of Stanley Kubrick's 2001: A Space Odyssey by Piers Bizony (Taschen).
 Artwork: Oliver Rennert/Taschen
 Photographs: Stanley Kubrick Archives/Taschen
 Dmitri Kessel/Getty Images
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Northern rights

Expect another decade of wrangling before competing claims over the North Pole are settled, says **Martin Pratt**

WHEN Russian scientists placed a flag on the seabed deep beneath the North Pole in 2007, it made headlines. But this did not make the pole Russian.

The more mundane act of the country's revised submission to the Commission on the Limits of the Continental Shelf (CLCS) this month is a more significant step in that direction, albeit one that may take many years to conclude.

With this fresh claim, Russia is seeking a substantial slice of the Arctic seabed. If granted, it would gain control over submerged resources, such as oil and gas.

Russia actually laid claim to the pole in 2001, when it made the first ever submission to the CLCS, set up under the United Nations Convention on the Law of the Sea. The commission helps states define the outer limit of their continental shelf, but only where this is more than 200 nautical



miles (370 kilometres) from the coast, the default limit for national rights.

It accepted parts of Russia's case then, but for the crucial central Arctic Ocean it wanted more data.

The full document – 13 years in the making and reportedly 2000 pages long – is confidential, but the executive summary argues that geological and geophysical research confirms Russia's original claim. This claim was that the Lomonosov ridge, the Mendeleev rise, the Chukchi rise, the Podvodnikov basin and the Chukchi basin form a single consolidated block of continental crust extending from its territory.

The 2015 submission features most of the 1.3 million square kilometres of seabed claimed in 2001. It also adds 103,000 square kilometres for good measure, including an area on the other side of the Pole, within the Arctic

No smoke, without ire

A smoking ban in jails will bring health gains, not riots. Let's do it, says **Deborah Arnott**

WHAT convinced me was a letter from a non-smoking inmate with lung cancer, upset at having to share his cell with smokers. This is a human rights issue and, if anything, it matters more in prisons than in public places.

Yet every time the idea of a smoking ban in prisons is raised, headlines focus on fears of unrest

and riots, rather than the health of inmates and staff.

The idea that depriving smokers of tobacco could be destabilising in prisons may sound plausible, but there is little evidence for it. Many jails have gone smoke-free with few problems, particularly if, as in New Zealand, measures such

as nicotine replacement therapy have been in place.

Smoking rates in prison are well above the average. Up to 80 per cent of UK inmates use tobacco, so exposure to second-hand smoke is high. But surveys show that most smokers in jail, like any others, want to quit. In New Zealand, over half who quit in jail want to stick to it on release.

Even the UK has precedents for going smoke-free without riots. Psychiatric detention facilities,

including high-security ones such as Broadmoor, went smoke-free in 2008 without any trouble. All juvenile jails have been so since 2007, and adult prisons on the Isle of Man and Guernsey have bans.

The privately run Parc prison in Bridgend will go smoke-free next February after a legal challenge forced the government's hand. It's time to roll out a ban nationally.

Inmates who want to quit smoking need services to help them do so. For those who do not, the prison service has a pilot scheme for them to buy electronic cigarettes, which ought to be extended to all jails.

Smoking is a costly addiction:

"Smoking rates are higher in prison... but most smokers in jail, like any others, want to quit"

sector where Canadian and Danish territories lie.

The case will probably be reviewed by the CLCS in 2016. Even if agreed, the seabed in question does not automatically become Russian. Denmark has lodged a claim, which argues that the Lomonosov ridge and North Pole are also an extension of its territory in Greenland.

The two claims overlap by 584,000 square kilometres and both may be at least partially valid. Canada may also make a submission similar to Denmark's. It could easily be another decade before the CLCS review is finished, and then governments will have to negotiate over how to carve up areas of overlapping entitlement.

Despite the headlines, there is no race to secure control of the Arctic Ocean. An established process for defining rights over seabed resources is enshrined in international law, and so far all Arctic states have followed that process scrupulously.

It is also worth noting that, however the continental shelf is divided, the water and ice of the central Arctic Ocean will remain high seas, owned by everyone and no one. ■

Martin Pratt is director of Bordermap Consulting, based in Alberta, Canada

it causes early death in some 100,000 smokers a year in the UK, and disability in many more.

The cultural change that has taken place everywhere else in society needs to be extended to prisons. Then inmates and staff need no longer put up with the harms caused by second-hand smoke, including a raised risk of respiratory and heart disease, and cancer. Once it happens, just as with bars going smoke-free, we'll look back and wonder what the fuss was about. ■

Deborah Arnott is chief executive of the London-based charity Action on Smoking and Health

ONE MINUTE INTERVIEW

Galaxies and stars for all

Our behemoth telescope will survey the southern sky – and everyone can have a play, says **Steve Kahn**



PROFILE

Steve Kahn is a professor of physics at Stanford University in California and director of the Large Synoptic Survey Telescope (LSST) project. Now under construction in Chile, it is expected to be operational by 2019

Why do we need another huge telescope?

The wide-angle LSST will map the entire southern hemisphere every few nights. For the first time in human history, we will have detected more galaxies than there are people on Earth. Everyone could have their very own galaxies and stars to study. We'll find 250,000 supernovae a year, track millions of asteroids every day. Among many other things, it will also teach us about dark matter, clumps of which should distort our images of distant galaxies.

What are the project's biggest challenges?

LSST is 10 times bigger than anything anyone is even planning, in terms of how much light it will collect and its field of view. The only way to build it is with three mirror bounces to cancel optical distortions, but nobody has ever made a big telescope fold light in this way. Such a large-field view needs the largest camera ever built – the size of a small car. It will have over 3 billion pixels, made up of 18916-megapixel units. The effort will create the biggest public data set in the world.

How much data will it generate?

Fifteen terabytes every night! Over a decade, the LSST will generate hundreds of petabytes of data, far more than everything ever written in history. Within 60 seconds we will get the data from the camera to a processing facility, detect everything in the image that has changed, and produce an automated alert stream. This will produce about 10 million alerts per night.

The idea to build the telescope goes back to the 1990s. Back then, these numbers were daunting. We relied on Moore's law: the expectation that computer processor speeds would continue to increase sharply while the cost and size of memory storage fell.

So how will you cope with the data deluge?

The big challenge is not acquiring and storing the data but how you find anything in a database that big. We'll have roughly 100 measurements (location, brightness, colour and so on) for each of 40 billion stars and galaxies, and we'll look at every object around 1000 times over the 10 years of operation. You can think of that as a 100,000-dimensional research space, containing 40 billion objects. There's a scale to the problem that's frightening.

It's a huge culture change for astronomy: most of the science will come from thinking of clever database queries. The best contributions probably won't come from astronomers but from mathematicians, computer scientists and statisticians.

And non-scientists can get involved. What was the thinking behind that?

Some of the LSST's donors, particularly in Silicon Valley, want to change the world, and on a personal scale. Science is the last bastion of having to go to a university and get a PhD, and there's a lot of influential people in the Valley saying: screw that, why can't smart, ordinary people play with cool things? You'll be able to log on and view the southern sky at any time, or join citizen science projects to measure gravitational lensing.

Interview by Mark Harris

Synthetic biology needs a grand vision

We can design a better future using biology, but we must consider the big questions first, says **Alexandra Daisy Ginsberg**

As a designer, what first appealed to you about synthetic biology?

In 2008, I heard scientists talking about engineering standard DNA components called BioBricks. These could be added to a bacterium to perform specific functions, the same way you add components to a circuit board. It sparked my interest in the big questions of designing living things: what will we design, how will we judge good design and what does it mean to design living things?

Synthetic biology is an area in which design itself hasn't yet been defined. There are scientists and engineers who say they're designing. But is what they're doing design or engineering? I think design can be more critical: it can help define a vision, and challenge and question.

How does this change the role of designers?

Today we view the designer as a mediator between new technologies and customers. A company may want to make a new kettle, so they will employ a designer in a service role to make it. I'm interested in disrupting that idea. There is a tradition of architects and designers as visionaries pursuing the social good. I look back to utopian architects like Le Corbusier, setting out a way of living that's manifested through design.

How have you explored our nascent relationship with synthetic biology?

I created a project called The Synthetic Kingdom, which was an exploration of synthetic biology and its future. Part of it was redesigning the tree of life – I was questioning whether genetically engineered “things” would still fit in with the taxonomy of life as we understand it. My solution was to add a

new kingdom, called synthetica, next to archaea, bacteria and eukarya.

I also designed fictional, biology-based objects to explore how they might be received. One idea was cups made out of keratin, a protein found in nails and hair. I was exploring how our relationship to such everyday goods might change if we re-engineered them out of material found in our own bodies.

What other designs have you produced that involve the human body?

I've joined in with the International Genetically Engineered Machine competition (iGEM) a few times, in which students design organisms using BioBricks. The University of Cambridge team I worked with designed bacteria that produced coloured pigments, which theoretically could be used to signal different levels of, say, pollutants – they called it *E. chromi*.

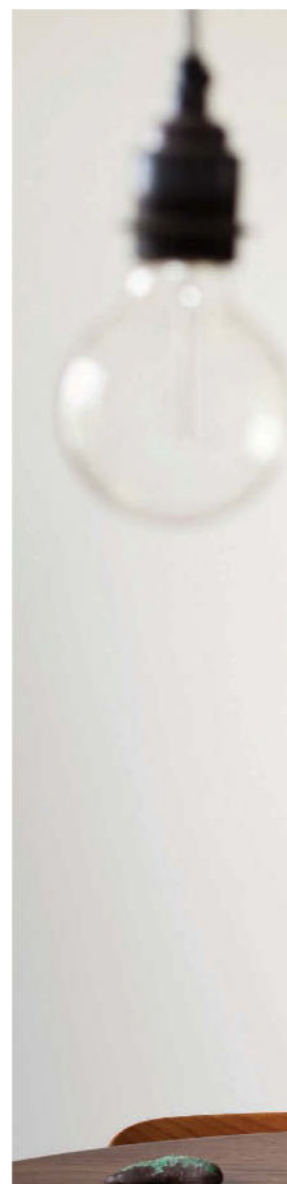
Speculative designer James King and I pushed it one step further, and came up with The Scatalog. It was based on a yoghurt containing *E. chromi* that would detect diseases or toxins in your gut and produce a coloured pigment in response, so your poo would change colour if you had specific health problems. We made a briefcase full of different coloured stools, which were actually made of plastic. We were essentially asking: will it ever be culturally acceptable to design in messy spaces like the gut?

You have a track record of involvement with thought-provoking, if unsettling, products...

I think the crowd pleaser is Selfmade, the human-body cheese created by synthetic biologist Christina Agapakis

PROFILE

Alexandra Daisy Ginsberg is a designer, artist and writer. After a degree in architecture, she studied design at Harvard University and London's Royal College of Art. She was a lead author on *Synthetic Aesthetics: Investigating synthetic biology's designs on nature* (MIT Press, 2014)



and Sissel Tolaas, an artist who works with smells. They met as part of a research project I was involved with between scientists, artists and designers called Synthetic Aesthetics. They immediately started talking about bacteria on the body.

A prevailing feeling is that bacteria in cheese are good, but bacteria on the body are bad. Yet the kind that make your feet smell of cheese are actually very close relatives of bacteria in cheese. So the way we think about these organisms is tempered by context and culture.

I had my armpit swabbed, and then the bacteria they took from me, and others, were made into cheese. We then ran a seminar at the Media Lab at the Massachusetts Institute



of Technology and passed the cheese around – we had “Daisy’s armpit”, “Philosopher’s toe” and various others.

What did people think of the cheeses made with bodily bacteria?

The reactions were extraordinary: “It’s disgusting, it’s wrong!” This wasn’t strictly synthetic biology, but it illustrates how the metaphors that permeate biological manipulation – of machinery, engineering and circuits – are a long way from the messy, material reality of it.

We’re being promised this future that’s powered by engineered bacteria, but we also have a real cultural problem with it.

You’ve also explored the tension between conservationists and synthetic biologists. Tell me about that.

These two groups are working in very different directions: conservationists try to preserve existing biodiversity, while synthetic biologists try to invent new biodiversity, purportedly of benefit to humans. I produced a work about this conflict of ambitions called *Designing for the Sixth Extinction*. It explored a future where nature had been “saved” by synthetic biology. The project imagines four biological machines – patented organisms – that are released into the wild to support endangered organisms or prop up failing ecosystems. One is a mobile bioremediation

unit, which looks like a slug and produces very alkaline slime. It is programmed to seek out and treat soil that has been ruined by acid rain.

How was this project received?

Designers liked it, but synthetic biologists said I was presenting a utopian future and that I’d disappoint the public because synthetic biology won’t be able to save nature. But in fact my view is dystopian: in effect, nature as we know it is destroyed in its saving, becoming completely infected with synthetic biology.

In reality, what do you feel about the direction that synthetic biology is taking?

It’s complicated. One original big ambition was to make biofuels. You grow sugar and feed it to your vat of synthetic organisms and they make fuel for you. But what’s happening is that it’s more profitable to make a litre of vanilla flavour than a litre of biofuel. So increasingly it’s being used to make specialty chemicals.

“I had cheese made using the bacteria swabbed from my armpit”

Is that necessarily a bad thing?

It all depends on your perspective. Vanilla, for example, is traditionally grown in Madagascar, in forests by local farmers who help preserve biodiversity by growing it among other trees. Compare that with vanilla that’s fed with sugar and grown in a vat. Chemically it’s identical, but at what level do we get to choose what we consume and how it’s made? How do we weigh up the benefits of such complex systems?

So you’re saying synthetic biology is a double-edged sword?

Yes, I think elements of synthetic biology could lead to new ways of doing things that could be better for the environment, say, or our health. But I think there are issues about the level of control we could ever achieve.

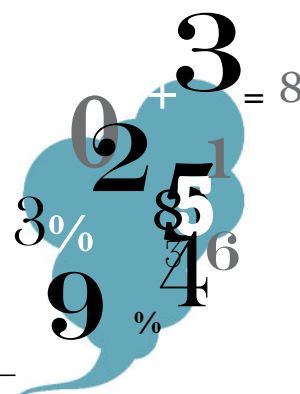
I also find synthetic biology within the human body troubling. We can see the potential – we might one day use it to alleviate Alzheimer’s or Parkinson’s – but we could also open the door to unintended consequences. Synthetic neurobiology is perhaps the most challenging. Some researchers are creating engineered human cells that could manipulate the way we feel. That opens up a very big can of worms. ■

Interview by Jeremy Webb

BEYOND KNOWLEDGE

We have always invented tools to take us beyond our natural abilities. But computers changed our ability to think, and they are now on the verge of transcending the limits of our ingenuity





Proof of concept

Computers can crack theorems humans struggle with. Could they extend mathematics itself, asks **Jacob Aron**

AFTER three years, Shinichi Mochizuki is still waiting. In 2012, the highly respected mathematician at Kyoto University in Japan published more than 500 pages of dense maths on his website. It was the culmination of years of work. Mochizuki's inter-universal Teichmüller theory described previously uncharted areas of the mathematical realm and let him prove a long-standing conundrum about the true nature of numbers, known as the ABC conjecture. Other mathematicians hailed the result, but warned it would take a lot of effort to check. Months passed, then years, with no conclusion.

Ask a mathematician what a proof is and they're likely to tell you it must be absolute – an exhaustive sequence of logical steps leading from an established starting point to an undeniable conclusion. But that's not the whole story. You can't just publish something you believe is true and move on; you have to convince others that you haven't made any mistakes. For a truly groundbreaking proof, this can be a frustrating experience.

It turns out that very few mathematicians are willing to put aside their own work and dedicate the months or even years it would take to understand a proof like Mochizuki's. And as maths becomes increasingly fractured into subfields within subfields, the problem is set to get worse. Some think maths is reaching a limit. Real breakthroughs can be too complicated for others to check, so many mathematicians occupy themselves with more attainable but arguably less significant problems. What's to be done?

For some, the solution lies in employing digital help. A lot of mathematicians already work alongside computers – they can help check proofs and free up time for more creative work. But it might mean changing

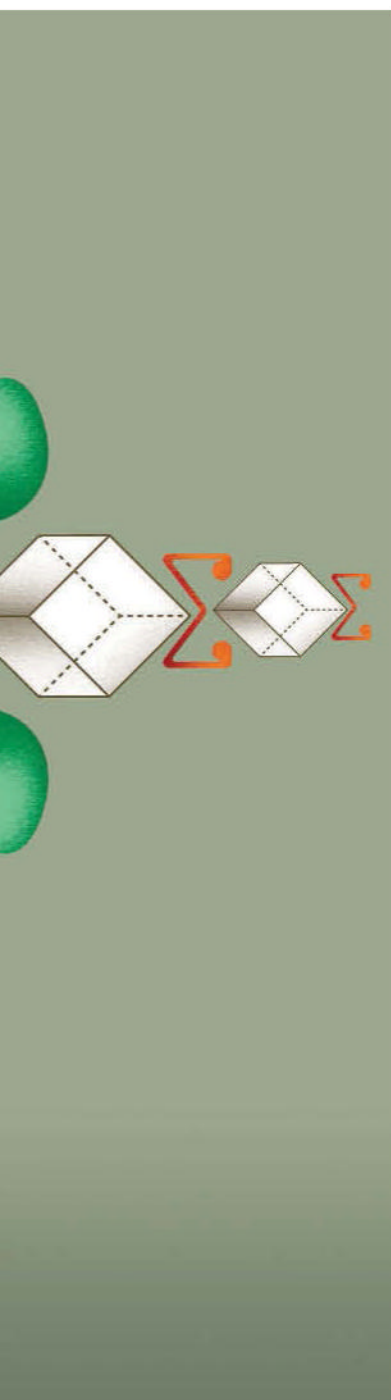
how maths is done. What's more, computers may one day make genuine breakthroughs on their own. Will we be able to keep up? And what does it mean for maths if we can't?

The first major computer-assisted proof was published 40 years ago and it immediately sparked a row. It was a solution to the four-colour theorem, a puzzle dating back to the mid-19th century. The theorem states that all maps need only four colours to make sure no adjacent regions are coloured the same. You can try it as many times as you like and find it to be true (see bit.ly/4colour to have a go). But to prove it, you need to rule out the very possibility of there being a bizarre map that bucks the trend.

In 1976, Kenneth Appel and Wolfgang Haken did just that. They showed you could narrow the problem down to 1936 sub-arrangements that might require five colours. They then used a computer to check each of these potential counterexamples, and found that all could indeed be coloured with just four colours.

Job done, or so you'd think. "Mathematicians were reluctant to accept this as a proof," says Xavier Leroy at the Institute for Research in Computer Science and Automation in Paris, France. What if there was an error in the code? "They said: 'We're not going to recheck your thousand particular cases by hand, we don't trust your program, and that's not a real proof.'"

They had a point. Checking software that tests a mathematical conjecture can be harder than proving it the traditional way, and a coding mistake can make the results totally unreliable. "It's very difficult to check whether a given program does the proper calculation just by inspection," says Georges Gonthier at Microsoft Research Cambridge, UK. "The computer goes over the code many times, so it can amplify even the smallest error." ➤



The trick is to use software to check software. Working with a type of program known as a proof assistant, mathematicians can verify that each step of a proof is valid. “It’s a fairly interactive process, you type commands into the tool and then the tool will spellcheck it, if you like,” says Leroy. And what if the proof assistant has a bug? It’s always possible, but these programs tend to be small and relatively easy to check by hand. “More importantly, this is code that is run over and over again,” says Gonthier. “You have massive experimental data to show that it is computing properly.”

However, using proof assistants means embracing a different way of working. When mathematicians write out proofs, they skip a lot of the boring details. There is no point in

“To make mathematical proof easier for computers, we must redefine maths itself”

laying out the foundations of calculus every time, for example. But such shortcuts don’t fly with computers. To work with a proof, they must account for every logical step, even apparent no-brainers such as why $2 + 2 = 4$.

Translating human-written proofs into computer-speak is still an active area of research. A single proof can take years. One early breakthrough came in 2005, when Gonthier and his colleagues updated the proof of the four-colour theorem, making every part of it computer-readable. Previous versions, ever since Appel and Haken’s work in 1976, relied on an area of maths called graph theory, which draws on our spatial intuition. Thinking about regions on a map comes naturally to humans, but not computers. The whole thing needed reworking.

“You have to turn everything into algebra, and that forces you to be more precise,” says Gonthier. “That precision ends up paying off.” Gonthier discovered that a part of the proof – widely assumed to be true because it seemed so obvious – had in fact never been proved at all because it was deemed not worth the effort. The assumption turned out to be correct, but it illustrates an added benefit of extra precision.

Tackling the four-colour theorem was just a warm-up, however. “It has relatively few uses in the rest of mathematics,” says Gonthier. “It was a brain-teaser.” So he turned to the Feit-Thompson theorem, a large and foundational proof in group theory from the 1960s. For many years the proof had been built upon and rewritten and it was eventually published in two books. By formalising it, Gonthier hoped

to demonstrate the computer’s capacity to digest a meatier proof that touched many different branches of mathematics. “The perfect test case,” he says.

It was a success. “In the process they found a couple of minor mistakes in the books,” says Leroy. “They were easily fixable, but still things that every human mathematician missed.” People took notice, says Gonthier. “I got letters saying how wonderful it was.”

In both cases, the result was never in doubt. Gonthier was taking well-established maths and translating it for computers. But others have been forced to redo their work in this way just to get their proofs accepted.

In 1998, Thomas Hales at the University of Pittsburgh, Pennsylvania, found himself in a similar position to Mochizuki’s today. He had just published a 300-page proof of the Kepler conjecture, a 400-year-old problem that concerns the most efficient ways to stack a collection of spheres. As with the four-colour theorem, the possibilities boiled down to variations on a few thousand arrangements. Hales and his student Samuel Ferguson used a computer to check them all.

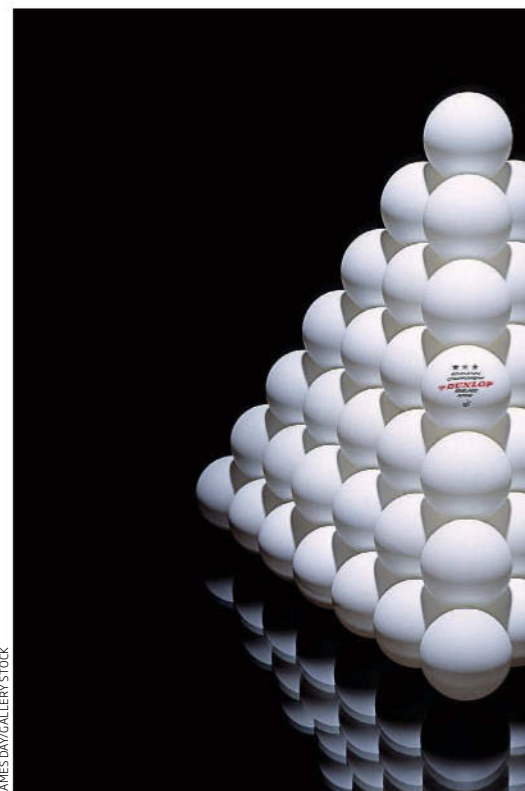
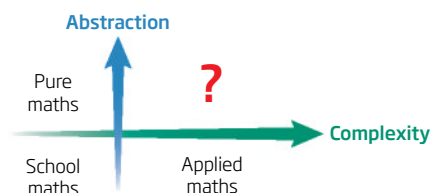
Hales submitted his result to the journal *Annals of Mathematics*. Five years later, reviewers for the journal announced they were 99 per cent certain that the proof was correct. “Referees in mathematics generally do not want to check computer code. They don’t see that as part of their job,” says Hales.

Convinced he was right, Hales started to rework his proof in 2003, so that it could be checked with a proof assistant. It essentially meant starting all over again, he says. He finally completed the project last year.

Gonthier’s and Hales’s research has shown that the approach can be applied to important mathematics. “The big theorems in maths that we’re proving now seemed a distant dream 10 years ago,” says Hales. But despite advances like the proof assistant, proving things with a computer is still a laborious process. Most mathematicians don’t bother.

Uncharted terrain

Maths that is both highly abstract and highly complex may be beyond human ability. Some think computers could open up this new territory for us



JAMES DAVICALLERY STOCK

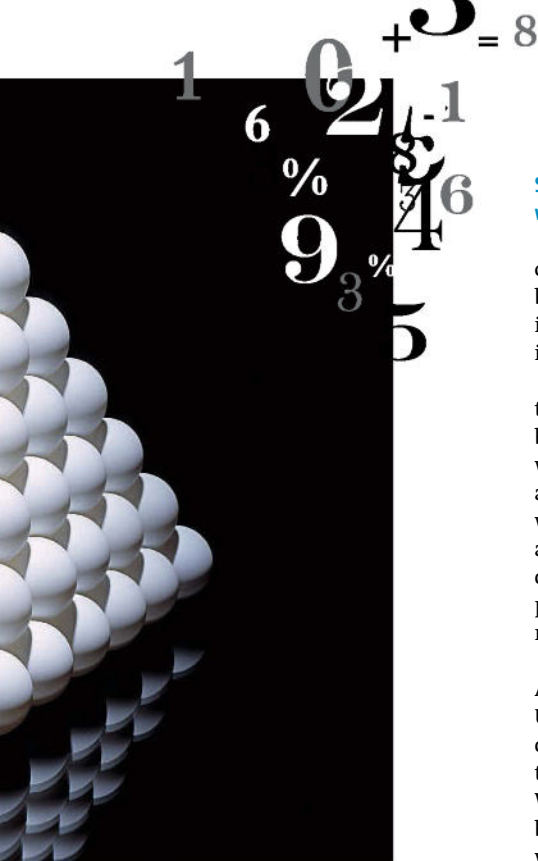
That’s why some are working in the opposite direction. Rather than making proof assistants easier to use, Vladimir Voevodsky at the Institute for Advanced Study in Princeton, New Jersey, wants to make mathematics more amenable to computers. To do this, he is redefining its very foundations.

True to type

This is deep stuff. Maths is currently defined in terms of set theory, essentially the study of collections of objects. For example, the number zero is defined as the empty set, the collection of no objects. One is defined as the set containing one empty set. From there you can build an infinity of numbers. Most mathematicians don’t worry about this on a day-to-day basis. “People are expected to understand each other without going down to that much detail,” says Voevodsky.

Not so for computers, and that’s a problem. There are multiple ways to define certain mathematical objects in terms of sets. For us, that doesn’t matter, but if two computer proofs use different definitions for the same thing, they will be incompatible. “We cannot compare the results, because at the core they are based on two different things,” says Voevodsky. “The existing foundations of maths don’t work very well if you want to get everything in a very precise form.”

Voevodsky’s alternative approach swaps sets for types – a stricter way of defining mathematical objects in which every concept has exactly one definition. Proofs built with



Software confirmed the best way to stack spheres

our everyday lives, involves low complexity but high abstraction. And school-level maths is neither complex nor abstract. But what lies in that fourth quadrant?

"It is very difficult at the present to go into the high levels of complexity and abstraction, because it just doesn't fit into our heads very well," says Voevodsky. "It somehow requires abilities that we don't possess." By working with computers, perhaps humans could access this fourth mathematical realm. We could prove bigger, bolder and more abstract problems than ever before, pushing our mastery of maths to ultimate heights.

Or perhaps we'll be left behind. Last year Alexei Lisitsa and Boris Konev at the University of Liverpool, UK, published a computer-assisted proof so long that it totalled 13 gigabytes, roughly the size of Wikipedia. Each line of the proof is readable, but for anyone to go through the entire result would take several tedious lifetimes.

The pair have since optimised their code and reduced the proof to 800 megabytes – a big improvement, but still impossible to digest. "From a human viewpoint, there's not much difference," says Lisitsa. Even if you did devote your life to reading something like this, it would be like studying a photograph pixel-by-pixel, never seeing the larger picture. "You cannot grasp the idea behind it."

Although it is on a far grander scale, the situation is similar to the original proof of the four-colour theorem, where mathematicians could not be sure an exhaustive computer search was correct. "We still don't know why the result holds true," says Lisitsa. "It could be a limit of human understanding, because the objects are so huge."

Doron Zeilberger of Rutgers University in Newark, New Jersey, thinks there will even

come a time when human mathematicians will no longer be able to contribute. "For the next hundred years humans will still be needed as coaches to guide computers," he says. But after that? "They could still do it as an intellectual sport, and play each other like human chess players still do today, even though they are much inferior to machines."

Zeilberger is an extreme case. He has listed his computer, nicknamed Shalosh B. Ekhad, as a co-author for decades and thinks humans should put pen and paper aside to focus on educating our machines. "The most optimal use of a mathematician's time is knowledge transfer," he says. "Teach computers all their tricks and let computers take it from there."

Spiritual discipline

But most mathematicians bristle at the idea of software that churns out proofs beyond human comprehension. "The idea that computers are going to replace mathematicians is misplaced," says Gonthier.

Besides, computer mathematicians would risk churning out an accelerating stream of unread papers. As it stands, scientific results often fail to garner the recognition they deserve, but the problem is particularly marked for maths. In 2014 there were more than 2000 maths papers posted to the online repository arXiv.org each month, more than in any other discipline, and the rate is increasing. "If you have too many new results that keep appearing, many just go unnoticed," says Leroy. Maybe we could at least create software to read everything and help humans keep up with the important bits, he says.

Gonthier feels this is missing the point: "Mathematics is not as much about finding proofs as it is about finding concepts." The nature of maths itself is under scrutiny. If humans do not understand a proof, then it doesn't count as maths, says Voevodsky. "The future of mathematics is more a spiritual discipline than an applied art. One of the important functions of mathematics is the development of the human mind."

All of this may be too late for Shinichi Mochizuki, however. His work is so advanced, so far removed from mainstream maths, that having a computer check it would be far more difficult than coming up with the original proof. "I don't even know if it would be possible to formalise what he's done," says Hales. For now, humans remain the ultimate judge – even if we don't always trust ourselves. ■

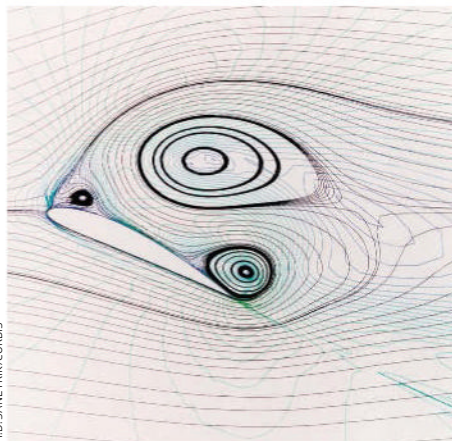
types can also form types themselves, which isn't the case with sets. This lets mathematicians formulate their ideas with a proof assistant directly, rather than having to translate them later. In 2013 Voevodsky and colleagues published a book explaining the principles behind the new foundations. In a reversal of the norm, they wrote the book with a proof assistant and then "unformalised" it to produce something more human-friendly.

This backwards working changes the way mathematicians think, says Gonthier. "The book is entirely written in non-formalised prose, but if you have any kind of experience with using the computer system, you quickly realise that the prose closely reflects what is going on in the formal system."

It also allows much closer collaboration between large groups of mathematicians, because they don't have to constantly check each other's work. "They've really started to popularise the idea that proof assistants can be good for the working mathematician," says Leroy. "That's a really exciting development."

And it may be just the beginning. By making maths easier for computers to understand, Voevodsky's redefinition might take us into new territory. As he sees it, mathematics is split into four quadrants (see chart, left). Applied maths – modelling the airflow over a wing, for example – involves high complexity but low abstraction. Pure maths, the kind of pen and paper maths that is far removed from

Modelling and visualising airflow is a task computers handle well



Jacob Aron is a reporter for *New Scientist*

Eureka machines

Inventors rely a lot on happenstance. Can computers help us make our own luck? **Paul Marks** investigates

ON A summer's day in 1899, a bicycle mechanic in Dayton, Ohio, slid a new inner tube out of its box and handed it to a customer. The pair chatted and the mechanic toyed idly with the empty box, twisting it back and forth. As he did so, he noticed the way the top of the box distorted in a smooth, spiral curve. It was a trivial observation – but one that would change the world.

The shape of the box just happened to remind the mechanic of a pigeon's wing in flight. Watching that box flex in his hands, Wilbur Wright saw how simply twisting the frame supporting a biplane's wings would give him a way to control an aircraft in the air.

Serendipity and invention go hand in hand. The Wright brothers' plane is just one of many examples. Take velcro: George de Mestral invented the material after he noticed the hook-covered seeds of the burdock plant sticking to his dog. And Harry Coover's liquid plastic concoction failed miserably as a material for cockpit canopies, as it stuck to everything. But it had a better use: superglue.

It may be romantic, but it is an achingly slow way to advance technology. Relying on happenstance means inventions that could be made today might not appear for years. "The way inventions are created is hugely archaic and inefficient," says Julian Nolan, CEO of Iprova, a company based in Lausanne, Switzerland, which specialises in generating inventions. Nothing has changed for hundreds of years, he says. "That's totally out of sync with most other industries."

But we are starting to make our own luck. Those eureka moments could soon be dialled up on demand as leaps of imagination are replaced by the steady steps of software. From algorithms that mimic nature's way of producing the best designs to systems that look for gaps between existing patented technologies that new designs might fill, computer-assisted invention is here.

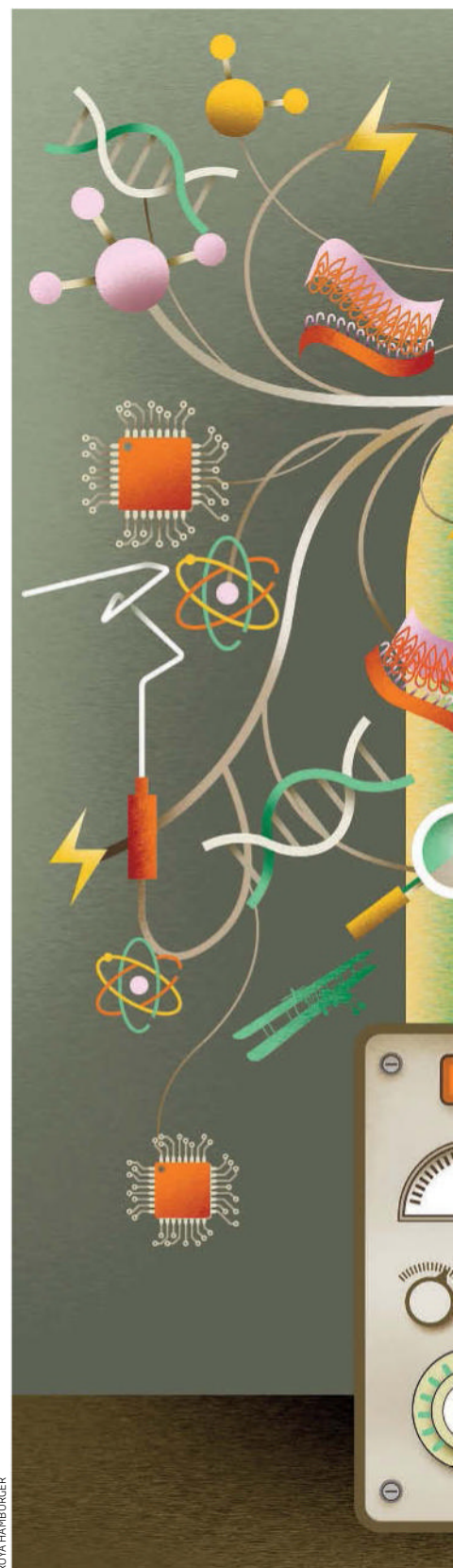
The impact could be huge. Some claim

automated invention will speed up technological progress. It could also level the playing field, making inventors of us all. But what happens if the currency of ideas is devalued? To qualify for a patent, for example, an idea can't be "obvious". How does that apply when ideas are found by brute force?

The first group to mimic evolution in patent design – pioneering the use of so-called genetic algorithms (see "As nature intended", page 34) – was led by John Koza at Stanford University in California in the 1990s. The team tested their algorithms by seeing if they could reinvent some of the staples of electronic design: the early filters, amplifiers and feedback control systems developed at Bell Labs in the 1920s and 1930s. They succeeded. "We were able to reinvent all the classic Bell Labs circuits," says Koza. "Had these techniques been around at the time, the circuits could have been created by genetic algorithms."

In case that was a fluke, the team tried the same trick with six patented eyepiece lens arrangements used in various optical devices. The algorithm not only reproduced all the optical systems, but in some cases improved on the originals in ways that could be patented.

The versatility of this type of algorithm is clear from the showcase of evolved inventions at the annual Genetic and Evolutionary Computation Conference (GECCO). Innovations at this year's event included efficient swimming gaits for a four-tentacled, octopus-like underwater drone – evolved by a team at the BioRobotics Institute in Pisa, Italy – and the most fuel-efficient route for a future space probe to clean up low-Earth orbits. Engineers at the European Space Agency's advanced concepts lab in Noordwijk, the Netherlands, treated the task like a cosmic version of the famous travelling salesman problem – but instead of cities, their probe visits derelict satellites and dead rocket bodies to nudge them out of orbit.



ROYA HAMBURGER



However, the big prize at GECCO is the human competitiveness award, or “Humie”, for inventions deemed to compete with human ingenuity. The first Humie, in 2004, was awarded for an odd-shaped antenna, evolved for a NASA-funded project. It worked brilliantly even though it looked like a weedy sapling, with a handful of awkwardly angled branches, rather than a regular stick-like antenna. It certainly wasn’t something a human designer would produce.

That is often the point. “When computers are used to automate the process of inventing, they aren’t blinded by the preconceived notions of human inventors,” says Robert Plotkin, a patent lawyer in Burlington, Massachusetts. “So they can produce designs that a human would never dream of.”

This year’s Humie winner was a way to improve the accuracy of super-low-power computers. So-called approximate computers are built from simple logic circuitry that consumes very little power but can make a lot of mistakes. By evolving smart software routines for such computers, Zdenek Vasicek at Brno University of Technology in the Czech Republic was able to correct many of the errors introduced by the simple design. The result is a greener chip for use in applications where computational exactness doesn’t matter, like streaming music or video.

There’s just one problem with using genetic algorithms: you need to know in advance what you want to invent so that your algorithm can modify it in fruitful ways. “Genetic algorithms work well when you already know all the relevant features and can vary them until you get a solution that satisfies all your fitness constraints,” says Tony McCaffrey, chief technology officer of Innovation Accelerator based in Natick, Massachusetts. Nolan agrees: “Genetic algorithms tend to be good at optimising pre-existing inventions but typically not ones of great commercial value.” That’s because they don’t take big, inventive steps, he says, and so have less chance of making a commercially valuable hit.

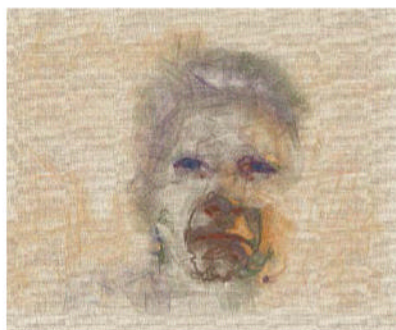
Innovation Accelerator’s approach is to use software to help inventors notice easily missed features of a problem that, if addressed, could lead to a novel invention. “An invention is something new that was not invented before because people overlooked at least one thing that the inventor noticed,” says McCaffrey. “If we can get people to notice more obscure features of a problem, we raise the chances that they will notice the key features needed to solve the problem.”

To do that, the firm has written software ➤

INTERVIEW

The art of programming

Computers can paint and make discoveries – the challenge is to teach them to code, says AI researcher **Simon Colton**



Simon Colton is professor of digital games technology at Falmouth University, UK. He works on software that behaves in ways that would be deemed creative if seen in humans – such as painting the image of him above

You designed software called HR to make its own discoveries. Has it had much success?

One thing HR came up with was a classification of mathematical structures known as Latin squares. Like a Sudoku puzzle, these are grids of symbols where each row and column contains every symbol. HR produced some of the first algebraic classifications of these structures.

A version of HR also independently came up with Goldbach's conjecture – that every even integer greater than 2 can be expressed as the sum of two primes.

Are mathematicians interested in using the system?

We found that mathematicians like software to do the boring grunt work – the massive calculations and trivial proofs they know are true. But creative things like inventing concepts and spotting conjectures they like to do themselves. I once sent Herbert Simon, the Nobel prizewinning economist and computer scientist, an email about a conjecture that HR had proved. He later told me that he hadn't read to the end because he wanted to solve the puzzle himself. His wife said she had to call him to bed.

How do you make software discover things?

You give it data that you want to find something out about, but rather than looking for known unknowns – as with machine learning, where you know what you're looking for but not what it looks like – it tries to find unknown unknowns.

We want software to surprise us, to do things we don't expect. So we teach it how to do general things rather than specifics. That contradicts most of what we do in computer science, which is to make sure software does exactly what you want. It takes a lot of effort for people to get their heads round it.

Can computers make breakthroughs?

I think we will only see computers making true discoveries when software can program itself. The latest version of HR is specifically designed to write its own code. But it's a challenge; it turns out that writing software is one of the most difficult things that people do. And, ultimately, there are mathematical concepts that you can't turn into code, especially ones dealing with infinity.

Another program of yours, The Painting Fool, creates portraits. How do people respond to this type of creativity?

Mathematicians will accept a computer as being creative if it produces great results over and over again. But in the art world, people take more convincing.

When you buy a painting you buy it for many reasons, only one of which is that it will look good with your sofa. When you like a painting, you're celebrating the humanity that went into it. How can we get software to fit in with that?

I don't want to do Turing tests where we try and confuse people about who or what is doing something. We want people to relate to what the software does on its own terms. But computers won't replace people in the creative industries because we will always pay for humanity – for blood, sweat and tears.

Interview by Douglas Heaven

One algorithm found a way to make helmets safer using magnets



BRIAN KERSY/PRESS ASSOCIATION

AS NATURE INTENDED

Genetic algorithms tackle the problem of design by mimicking natural selection. Desired characteristics are described as if they were a genome, where genes represent parameters such as voltages, focal lengths, or material densities, say.

The process starts with a more or less random sample of such genomes, each a possible, albeit suboptimal, design. By combining parent genomes from this initial gene pool – and introducing “mutations” – offspring are created with features of each parent plus potentially beneficial new traits. The fitness of the offspring for a given task is tested in a simulation. The best are selected and become the gene pool for the next round of breeding. This process is repeated again and again until, as with natural selection, the fittest design survives (see diagram, opposite).

As well as evolving new designs, evolutionary algorithms can be used to evolve “parasites” that inflict maximal damage to test safety or security features. “Nature has been very good and very creative at finding loopholes in every possible complex system,” says Eric Bonabeau of Icosystem of Cambridge, Massachusetts, who has used this technique to improve the design of ships for the US navy.



that lets you describe a problem in human language. It then “explodes” the problem into a large number of related phrases and uses these to search the US Patent and Trademark Office database for inventions that solve similar problems. But similar is the operative word, says McCaffrey. The system is designed to look for analogues to the problem in other domains. In other words, the software does your lateral thinking for you.

In one example, McCaffrey asked the system to come up with a way to reduce concussion among American football players. The software exploded the description of the problem and searched for ways to reduce energy, absorb energy, exchange forces, lessen momentum, oppose force, alter direction and repel energy. Results for how to repel energy led the firm to invent a helmet that contained strong magnets to repel other players’ helmets, lessening the impact of head clashes. Unfortunately, someone else beat them to the patent office by a few weeks. But it proved the principle, says McCaffrey.

In another case, the software duplicated a ski-maker’s recent innovation. The problem was to find a way to stop skis vibrating so skiers could go faster and turn more safely. The manufacturer eventually stumbled upon an answer, but Innovation Accelerator’s software was able to find it quickly. “A violin builder had a method to produce purer music by reducing vibrations in the instrument,” says McCaffrey. “The method was applied to

the skis and made them vibrate less.”

“Ninety per cent of problems have already been solved in some other field,” says McCaffrey. “You just have to find them.” He now plans to use IBM’s supercomputer Watson, which draws inferences from millions of documents, to help his system understand patents and technical papers far more deeply.

The technology at Nolan’s firm, Iprova, also helps inventors to think laterally – but with ideas derived from sources far beyond patent documents. The company is unwilling to reveal exactly how its Computer Accelerated Invention technique works, but in a 2013 patent, Iprova says it provides clients with “suggested innovation opportunities” by interrogating not only patent databases and technical journals, but also blogs, online news sites and social networks.

Of particular interest is the fact that it alters its suggestions as tech trends on the internet change. The result seems to be extremely productive. “We use our technology to create hundreds of high-quality inventions per month, which we then communicate to our customers,” says Nolan. “They can then choose to patent them.” If their wide range of customers in the healthcare, automotive and telecommunications industries is anything to go by, Iprova appears to have hit paydirt. One of its clients is Philips, a major technology multinational. Such firms don’t add outside expertise to their R&D teams lightly.

All this means that algorithm-led discovery is likely to be the most productive inventing process of the future. “Human inventors who learn to leverage computer-automated

innovation will leapfrog peers who continue to invent the old-fashioned way,” says Plotkin

But where do we draw the line between the two? “I don’t think there is a clear separation between human and algorithm,” says Eric Bonabeau, founder of Icosystem, a company based in Cambridge, Massachusetts. “The key is to find the right division of labour.”

Icosystem uses genetic algorithms to optimise everything from inventions to business

“Human inventors who use automated innovation will leapfrog those who don’t”

processes – an approach Bonabeau calls “enhanced serendipity”.

However, if the division of labour is too much on the computer’s side, it could undermine the patent system itself. Currently a “person having ordinary skill in the art” must believe that an invention isn’t obvious if it is to be granted a patent. But if inventors are only tending a computer, the inventions that arise could be deemed an obvious output of that computer, like hot water from a kettle.

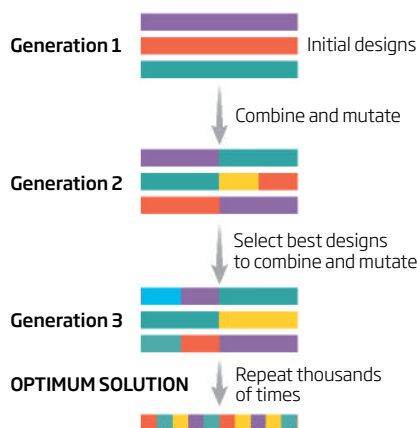
These concerns have already been raised with drug discovery, says Gregory Aharonian, a consultant based in San Francisco, who specialises in patents. “If drug discovery tools become so powerful that a researcher is just overseeing the tools’ activity, does that make the whole process obvious and so not patentable? Industry could be shooting itself in the foot by developing such technology.”

Another concern is that broad access to smart invention tools could speed up human technological development. Making the resulting gadgets may consume Earth’s resources all the quicker. McCaffrey is more optimistic. “I am really impressed with engineers who are creating ways to improve housing, food storage, crop growth, water purification and transportation in the developing world,” he says. “I sincerely hope we use this emerging invention assistance technology to address the really important problems faced by humanity.”

Chance favours the prepared mind. If Wilbur Wright hadn’t been thinking about his problem, he may never have had his eureka moment. “Automating that amounts to making accidental encounters orders of magnitude more efficient,” says Bonabeau. “In other words, outsource serendipity to the algorithm.” ■

It’s evolutionary

Genetic algorithms try to find the optimum solution to a problem by repeatedly combining and mutating the best in each generation of potential solutions



Paul Marks is a freelance journalist based in London



BORED? WELL, DON'T BE

The true nature of boredom turns out to be far more stimulating than you might think, finds **Caroline Williams**

AS I sit, trying to concentrate, my toes are being very gently nibbled. It's my dog, Jango, an intelligent working breed, and he's telling me that he is bored. I know from experience that if I don't take him out right now, or at least find him a toy, he will either pull my socks off and run away with them, or start barking like a beast possessed.

His cousins in the wild don't seem to suffer the same problem. Coyotes spend 90 per cent of their time apparently doing nothing, but never seem to get fed up, according to Marc Bekoff at the University of Colorado in Boulder, who has studied them for years. "They might be lying down but their eyes are moving and their heads are moving and they are constantly vigilant," he says. Trapped indoors, Jango has little to be vigilant about, and a lot of spare mental capacity. Bored office workers everywhere will know the feeling.

We tend to think of boredom as a price we pay for being intelligent and self-aware. Clearly we aren't the only species to suffer. Yet, given how common this emotion is in daily life, it's surprising how little attention it has received. Now that is changing and, as interest increases, researchers are addressing some fascinating questions. What exactly is boredom? Why are some people more prone to it than others? What is it for? Is it a good or bad thing? And what can we do to resist it when it strikes? Some of the answers are hotly contested – boredom, it

turns out, is really rather stimulating.

Like other emotions, boredom didn't just arise spontaneously when humans came on the scene. Many creatures, including mammals, birds and even some reptiles, seem to have a version of it, suggesting that there is some kind of survival advantage to feeling bored. The most plausible explanation is that it serves as a motivator. Boredom could have evolved as a kind of kick up the backside, suggests animal psychologist Francoise Wemelsfelder at the Scottish Agricultural College in Edinburgh, UK. "If a wild animal has done nothing for a while there is a lot of evidence that it will go out to look for things to do, and there is definitely survival value in that," she says. It will know, for example, that an escape route is blocked, because it has explored its territory.

Where boredom stops being useful and starts becoming a problem is when the desire to explore is thwarted. "All animals want and need to engage with the environment," says Wemelsfelder. That's why they get bored if you put them in a plain wire cage and, if left there, may end up exhibiting strange behaviours such as pacing in a figure of eight or pulling out their own feathers. "Even if they don't sit there thinking, 'damn I'm bored', I still think they suffer," she says.

Human boredom may be more complex, but there are parallels. In his book, *Boredom: A lively history*, Peter Toohey at the University

continued on page 40 ➤

 **Boredom is the dream bird that hatches the egg of experience**

WALTER BENJAMIN

CYRUS CORNUT/DOLCE VITA/PICTURETANK

FASCINATING BOREDOM

Do boring people get bored?

It is sometimes said that only boring people get bored. That is almost certainly unfair, but some people clearly suffer more than others. The standard way to measure a person's propensity to boredom is the boredom proneness scale (BPS), first published in 1986 by Richard Farmer and Norman Sundberg of the University of Oregon (to take the test, see right).

So who is easily bored? Studies using the BPS indicate that men get bored more than women, that extroverts are prone, as are people with narcissistic personality traits, anxious types and those who lack self-awareness. Highly

competitive sorts who are also sensation-seekers are particularly prone, which has led some to suggest a link between boredom and a heightened desire for stimulation caused by low levels of the "pleasure" neurotransmitter dopamine. On the other hand, creative people and those with a higher need for mental stimulation seem to be protected from boredom to some extent, perhaps because they do better at finding some interest or meaning in whatever they have to do.

But it's not just about your boredom threshold; how intensely you experience boredom also matters. "You might not

score high on boredom proneness but in the moment, you might still be really bored," says John Eastwood at York University in Toronto, Canada. He prefers to see boredom as a state, rather than a trait, and has developed his own test – the multidimensional state boredom scale – to measure how it feels in the here and now.

Nothing evokes this state quite as well as feeling trapped in a situation where you have no control over your choices. So it's not about being boring. "Only captive people get bored" might be a more accurate statement.

You might be interested to know...

6 hours

An average Briton is bored each week

online survey www.triviala.com

73 %

People who believe boredom can be positive

Journal of Applied Social Psychology, vol 30, p 576

1 in 10

People who claim to never be bored

Journal of Applied Social Psychology, vol 30, p 576

What's your boredom style?

Boredom takes five distinct forms depending on how negative and how energetic you feel. You may experience them all, but one kind will be your specialty. Which is it?

Do you tend to experience boredom as a benign or even positive state?

IF YES

YOU SPECIALISE IN INDIFFERENT BOREDOM

When bored you most often feel relaxed and calm, not particularly fed up, but not engaged with the world. This is the most positive type of boredom. It may even lead to creativity.

IF NO

When bored, are you typically very fidgety and tense?

IF YES

YOU SPECIALISE IN REACTANT BOREDOM

The explosive combination of high arousal and negative emotion leaves you restless, angry and in need of an outlet. This is the most damaging form of boredom.

IF NO

Do you experience boredom as an extremely negative feeling?

IF YES

YOU SPECIALISE IN APATHETIC BOREDOM

When bored you tend to feel disengaged and unable to do anything about it. This especially unpleasant type of boredom is most similar to depression and learned helplessness.

IF NO

Keeping you awake?

The boredom proneness scale was devised in 1986 by Richard Farmer and Norman Sundberg of the University of Oregon. It is now accepted as a standard way to measure your propensity for boredom, although we have reworded several items to simplify scoring. By the way, if manually calculating a score sounds boring, our online quiz can do it for you at bit.ly/NSboredom.

Answer the questions using a scale from 1 to 7, where 1=highly disagree, 4=neutral, 7=highly agree

- 1 It is not easy for me to concentrate on my activities.
- 2 Frequently when I'm working I find myself worrying about other things.
- 3 Time always seems to be passing slowly.

- 4 I often find myself at "loose ends", not knowing what to do.
- 5 I am often trapped in situations where I have to do meaningless things.
- 6 Having to look at someone's home movies or travel slides bores me tremendously.
- 7 I do not have projects in mind all the time, things to do.
- 8 I find it hard to entertain myself.
- 9 Many things I have to do are repetitive and monotonous.
- 10 It takes more stimulation to get me going than most people.
- 11 I get a kick out of few things I do.

- 12 I am seldom excited about my work.
- 13 In many situations I can find nothing to do or see to keep me interested.
- 14 Much of the time I just sit around doing nothing.
- 15 I am not good at waiting patiently.
- 16 I often find myself with nothing to do – time on my hands.
- 17 In situations where I have to wait, such as a line or a queue, I get very restless.
- 18 I rarely wake up with a new idea.
- 19 It would be very hard for me to find a job that is exciting enough.

- 20 I would like more challenging things to do in my life.
- 21 I feel that I am working below my abilities most of the time.
- 22 Few people would say that I am a creative or imaginative person.
- 23 I have few interests and lots of spare time.
- 24 Among my friends, I am the one who gives up on things first.
- 25 Unless I am doing something exciting, even dangerous, I feel half-dead and dull.
- 26 It takes a lot of change and variety to keep me really happy.

- 27 It seems that the same things are on television or the movies all the time; it's getting old.
- 28 When I was young, I was often in monotonous and tiresome situations.

HOW YOU SCORED

Below 81 You don't bore easily at all. You find amusement in the slightest thing and life is continually interesting. Lucky you!

81 to 117 You get bored sometimes, but these scores reflect average levels. Try to put those down times to good use!

Above 117 You get bored so easily you probably dropped off while reading this. On the bright side, provided you have the right kind of boredom (see below) creativity might come more easily to you, helping you avoid the intolerable dull life.

SOURCE FOR KEEPING YOU AWAKE?: BOREDOM PRONENESS—THE DEVELOPMENT AND CORRELATES OF A NEW SCALE BY RICHARD FARMER & NORMAN D. SUNDBERG, MARCH 1986; TAYLOR & FRANCIS
SOURCE FOR WHAT'S YOUR BOREDOM STYLE? DIAGRAM: MOTIVATION AND EMOTION, VOL 38, P401

When bored, do you tend to look for ways to alleviate the feeling?

IF YES YOU SPECIALISE IN SEARCHING BOREDOM

Being bored makes you feel negative and restless. You actively seek ways to alleviate your boredom and if you fail to find diversions it may become reactant.

IF NO

YOU SPECIALISE IN CALIBRATING BOREDOM

For you, boredom feels unpleasant but you tend not to look for ways out of it, although you are open to boredom-reducing options if they should arise.



The cure for boredom is curiosity. There is no cure for curiosity

DOROTHY PARKER

◀ of Calgary, Canada, compares it to disgust – an emotion that motivates us to avoid certain situations. “If disgust protects humans from infection, boredom may protect them from ‘infectious’ social situations,” he suggests. And, as with other animals, boredom seems to occur when we feel physically or mentally trapped. One study, for example, found that people given no choice but to participate in a dull activity in the lab reported that time dragged, and rated the task as more boring than those who had chosen to participate.

We all know how it feels – it’s impossible to concentrate, time stretches out, a fog descends and all the things you could do seem equally unlikely to make you feel better. But defining boredom so that it can be studied in the lab has proved difficult. For a start, it isn’t simply about aversion or feeling trapped, but can include a lot of other mental states, such as frustration, apathy, depression, indifference and surfeit. There isn’t even agreement over whether boredom is always a low-energy, flat kind of emotion or whether feeling agitated and restless counts as boredom, too.

Thomas Goetz at the University of Konstanz in Germany suspects it can be all of these

Doing a repetitious, monotonous task may bore you, but it could also make you more creative

things. By asking people about their experiences of boredom, he and his team have recently identified five different types: indifferent, calibrating, searching, reactant and apathetic (see “What’s your boredom style?” page 38). These can be plotted on two axes – one running left to right, which measures low to high arousal, and the other from top to bottom, which measures how positive or negative the feeling is. Intriguingly, Goetz has found that while people experience all kinds of boredom, and might flit from one to another in a given situation, they tend to specialise in one. However, it remains to be seen whether there are any character traits that predict the kind of boredom each of us might be prone to.

Of the five types, the most damaging is “reactant” boredom with its explosive combination of high arousal and negative emotion, which adds up to a restless, angry person in need of an outlet. The most useful is what Goetz calls indifferent boredom: someone isn’t engaged in anything satisfying but neither are they particularly fed up, and actually feel relaxed and calm. He believes that in the right circumstance this type of boredom can be a positive experience.

“If you have a hard day and in the evening you go to a class, it might be boring but it’s OK to be bored because you had a stressful day. Time feels like it’s standing still, but it’s not too bad,” he says.

Psychologist Sandi Mann at the University of Central Lancashire, UK, goes further. She believes this positive kind of boredom and, to some extent all kinds, can be good for us.

“All emotions are there for a reason, including boredom,” she says. As well as motivating us to do something more interesting, Mann has

found that being bored makes us more creative. “We’re all afraid of being bored but in actual fact it can open our minds, it can lead to all kinds of amazing things,” she says.

In experiments published last year Mann found that people who had been made to feel bored by copying numbers out of the phone book for 15 minutes came up with more creative ideas about how to use a polystyrene cup than a control group who had gone straight to the cup problem. People who just read the phone book for 15 minutes were more creative still. Mann concluded that a passive, boring activity is best for creativity because it allows the mind to wander. In fact, she goes so far as to suggest that we should seek out more boredom in our lives.

Psychologist John Eastwood at York University in Toronto, Canada, isn’t convinced. “If you are in a state of mind-wandering you are not bored,” he says. “In my view, by definition boredom is aversive, it’s an undesirable state.” That doesn’t necessarily mean that it isn’t adaptive, he adds. “Pain is adaptive – if we didn’t have physical pain, bad things would happen to us. Does that mean that we should actively cause pain? No.” In other words, even if boredom has evolved to help us survive, it can still be toxic if allowed to fester. “All emotions tell us how we are in



MARY EVANS/CLASSIC STOCK/H. ARMSTRONG ROBERTS

The two enemies of human happiness are pain and boredom

ARTHUR SCHOPENHAUER



ANDREW TESTA/PANOS



Ennui or not ennui? Boredom isn't caused by a lack of stimulation but by a failure to focus

the world. Boredom tells us we have pent-up, unused potential and desire to connect to the world. Then the question is what do I do to cope with that situation?" Eastwood says.

Eastwood is interested in what boredom actually is – and his model highlights why it can be so difficult to cope with. For him, the central feature is a failure to switch our attention system into gear. The problem isn't so much a lack of stimulating things to do, but trouble focusing on anything. With nothing to focus your attention away from the passage of time, it seems to go painfully slowly. What's more, your efforts to rectify the situation can end up making you feel worse. "People try to connect with the world and if they are not successful there's that frustration and irritability," he says. "Then they fall back into lethargy and if that doesn't work they get aroused again, so there's an oscillation between the under and over-arousal states in an attempt to resolve the problem." Perhaps most worryingly, says Eastwood, repeatedly failing to engage attention can lead to a state where we don't know what to do any more, and no longer care.

Eastwood's group is now exploring why the

attention system fails. It's early days but they think that at least some of it comes down to personality. Boredom proneness has been linked with a variety of traits (see "Do boring people get bored?" page 38). People who are motivated by pleasure – the sensation-seeking stimulation junkies – seem to suffer particularly badly, as do anxious types. Other personality traits, such as curiosity and self-control, are associated with a high boredom threshold. What Eastwood's team would like to know is why the attention system is prone to fail in some types of people more than others, what this suggests about the neuroscience of attention failure, and whether this can tell us anything about why some people experience boredom more than others.

Bored to death?

Whatever its cause, a failure to focus might help explain why boredom feels bad. Psychologists Matthew Killingsworth and Daniel Gilbert at Harvard University used a smartphone app to interrupt people at random intervals to ask them if they were on-task and how happy they felt. It turned out that the unhappiest people were those who were least focused on what they were supposed to be doing.

More evidence that boredom has detrimental effects comes from studies of people who are more or less prone to boredom. It seems those who bore easily face poorer prospects in education, their career and even life in general. They are also more likely to have problems with anger and aggression, and to partake in risky behaviours such as alcohol and drug abuse and gambling. One study even seemed to suggest that it's

Boredom is the root of all evil – the despairing refusal to be oneself

SOREN KIERKEGAARD

Boredom: the desire for desires

LEO TOLSTOY

possible to be bored to death. Researchers from University College London looked at self-rated boredom levels in civil servants in 1985. When they followed them up in 2009, they found those who had been consistently bored were significantly more likely to die early.

Of course, boredom itself cannot kill, it's the things we do to deal with it that may put us in danger. What can we do to alleviate it before it comes to that? Goetz's group has one suggestion. Working with teenagers, they found that those who "approach" a boring situation – in other words, see that it's boring and get stuck in anyway – report less boredom than those who try to cope by avoiding it and mucking around. So when boredom strikes, distracting yourself from the feeling with snacks, TV or social media probably isn't the best strategy.

In fact our techno-loaded, overstimulated lives might be part of the problem. Mann believes that with so many distractions we are neglecting our ability to daydream. "We have this inbuilt mechanism to cope with boredom, but we're not using it," she says. Wemelsfelder speculates that our overconnected lifestyles might even be a new source of boredom.

"In modern human society there is a lot of overstimulation but still a lot of problems finding meaning," she says. So instead of seeking yet more mental stimulation, perhaps we should leave our phones alone, listen to the boredom and use it to motivate us to engage with the world in a more meaningful way.

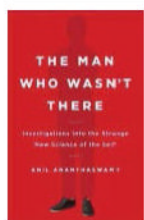
If that sounds too hard, technology itself might provide an answer in the future. Sidney D'Mello at Notre Dame University in Indiana is working on a computer-based tutor for use in schools. By tracking eye position and body posture, it can tell when a person is getting bored, and will adjust its instructions accordingly. It's not difficult to imagine a similar program sitting on every office desktop, waiting to cajole you back into action. Ironically, it might turn out to be one kind of techno-distraction that we find incredibly easy to turn off. ■

Caroline Williams is a writer based in Surrey, UK

This thing called me

People with “broken” selves are teaching us a lot about being human, finds **Alun Anderson**

The Man Who Wasn't There: Investigations into the strange new science of the self by Anil Ananthaswamy, Dutton, \$26.95



FOR ordinary folk, a unified sense of self is taken for granted. We sit comfortably inside a body we feel is ours, seeing, hearing, touching

and smelling. Gloomy or happy, our feelings plainly belong to us. We own our bodily actions, whether picking up a cup of coffee or playing tennis, and we can travel back and forth in time, remembering things uniquely part of our life history and imagining our future. This self appears to us seamlessly and effortlessly as a whole.

The Man Who Wasn't There could be described as a dedication to a different group – those whose unity of self has fragmented – and to the way they have helped us understand the self through their cooperation with scientists and philosophers, and their long hours in brain scanners.

To write it, Anil Ananthaswamy, formerly of *New Scientist's* staff, travelled the world to meet scores of people with “maladies of the self”. It is an astonishing journey and an ambitious book, bringing together cutting-edge science and philosophy from West and East. You will not be quite the same self after reading it.

Ananthaswamy encounters those who think they are dead, who feel their limbs don't belong to them, who travel outside their own bodies or, more dramatically, have met a doppelgänger. There are autistic people; people



HERBERT LIST/MAGNUM PHOTOS

experiencing depersonalisation and schizophrenia; those who have glimpsed ecstatic union during epilepsy; and those whose selves seem to be vanishing under the onslaught of Alzheimer's. It is to the author's credit that he never depicts his subjects as “patients” or “sufferers”, but as people who can describe a phenomenal self

“The ‘rubber-hand’ illusion can shift your experience of where you are to a body as small as a Barbie doll”

that is simply different.

That self can sometimes be so different that it leads to actions which shock. Ananthaswamy travels to an unnamed Asian city with “David”, who has body integrity identity disorder (BIID), the sense that not all of his body

truly belongs to him. For decades, he has felt that one of his legs is not part of his body. Ananthaswamy waits outside the operating theatre while David's leg is amputated. David emerges having finally found happiness, like many others with BIID who decide that life as an amputee is better than life with an alien limb.

A fundamental point is how the sense of self is grounded in the body, its feelings and our brain's maps of them. Mismatches between inputs or wrongly constructed maps can leave the brain struggling for the right answer. Sometimes the strange upshot is the sense that a limb does not belong to us, or even that our body is separate from us.

This might seem far-fetched if it were not easy to bring about shifts in the boundaries of our

Some disorders may be rooted in a clash of signals into the brain

bodies. At the Karolinska Institute in Stockholm, Sweden, Ananthaswamy experiences the well-known “rubber-hand” illusion. He sits at a table and rests one hand on it. A rubber hand is placed nearby and a screen hides his view of his own hand. An experimenter strokes both his real hand and the fake one.

Before long, Ananthaswamy feels the stroking sensation somehow transfer to the location of the rubber hand. The brain has reconciled the conflicting sensations by transferring ownership of the rubber hand to him. Surprisingly, he explains, a scaled-up version can shift your experience of where you are to another body, or to virtual bodies

“as small as Barbie dolls or as big as a thirteen-foot-high-giant”.

His travels reveal that the same broad idea – of a brain trying to make predictive sense of sometimes conflicting internal and external signals – can give insights into how many “maladies of self” develop. People with schizophrenia may lack agency, the sense that they are carrying out their own actions. The brain compensates by trying to make judgements about the ownership of their actions from a more external viewpoint, which may force them to feel almost outside themselves.

Unnervingly fluid

There is also good evidence that people with autism can have a less fixed perception of their own body. The resulting anxiety may lead to a characteristically intense desire for external order.

These are just two examples of a speculative, emerging view of the self that the book uncovers. Alongside, much emerges about the brain regions involved, the emphasis returning repeatedly to the anterior insula’s key role in the moment-to-moment sense of self as a feeling entity. Under-activation here correlates with the fog of depersonalisation, over-activation to a unifying ecstasy.

By the book’s close, you will see the unified self as an unnervingly fluid construction, and perhaps be able to argue with Buddhist, Hindu and Western philosophers on the very existence of “self”.

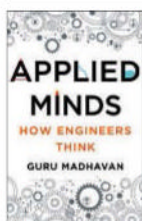
The book has just one shortcoming. Ananthaswamy writes dispassionately about the people he meets. Only in the acknowledgments do his warm feelings towards them shine through. If he had let us in on the personal passion behind his great quest, we would have a book that is not just excellent but also impossible to put down. ■

Alun Anderson is a consultant for *New Scientist*

An engineer’s lot

Why do we only care when things screw up, asks **Jonathon Keats**

Applied Minds: How engineers think, by Guru Madhavan, W.W. Norton, \$26.95

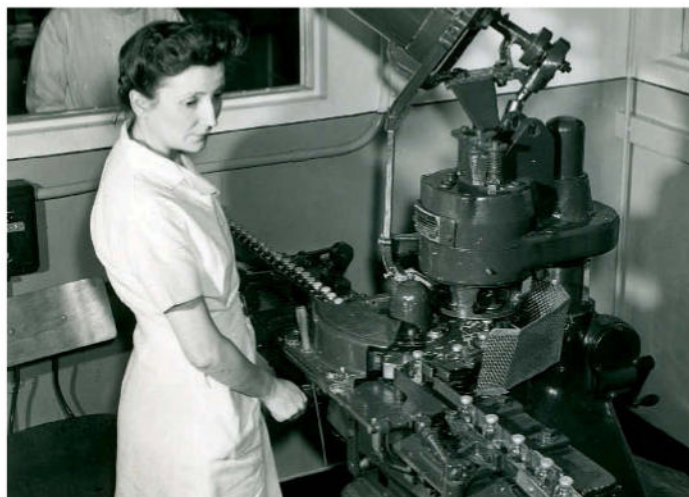


THE discovery of penicillin is one of the greatest breakthroughs in medicine. Yet in 1942, more than a decade after Alexander Fleming first identified it, quantities were so limited that doctors used half of the US supply to treat one patient.

As the nation went to war, military demand soared and pharmaceutical company Pfizer assigned the mass production of the antibiotic to a chemical engineer named Margaret Hutchinson. The technique she developed produced 650 billion doses for the Allies by 1945.

Unlike Fleming, Hutchinson never became famous, an oversight that biomedical engineer Guru Madhavan attributes to her profession.

Unrecognised creativity: engineers are omnipresent but invisible



“Engineering is omnipresent but invisible,” he writes. “It tends to be discussed only when an airplane crashes... a building crumbles, or a technology fails.”

In *Applied Minds*, Madhavan sets out to remedy this, claiming for engineering the credit he says the profession deserves. For him, engineers are the most significant actors in modern society. They are “propellers of economies, designers of our material destinies... and subliminal brokers who facilitate our experiences with the world”. We need to understand what they do and how they think for the same reasons that it behoves us to understand our national governments.

But in contrast to government, where our main concern is that politicians act responsibly on our behalf, engineering provides a “multi-purpose tool kit” that Madhavan believes we all can use.

To elucidate, Madhavan’s vivid cameos range from the 18th-century development of French artillery to the 21st-century implementation of Google Maps.

Between these temporal bookends are tales of time zones, digital cameras and disposable nappies.

From each example, Madhavan attempts to draw broader lessons. But more often than not, he fails. For instance, his account of how Martin Cooper developed the first cellphone for Motorola identifies prototyping as key, but Madhavan remains frustratingly vague about how the DynaTAC benefited from prototyping, let alone why it is a skill we all need. “Prototypes are

“Margaret Hutchinson produced industrial quantities of penicillin from mouldy cantaloupe”

the starting points toward our ultimate creative destinations,” he writes. The same could be said of blueprints or designs.

Madhavan does better with penicillin. Working under great pressure, Hutchinson enlisted Pfizer’s citric acid fermentation tanks as well as chemical purification techniques for petrol refinement to help her extract industrial quantities of penicillin from mouldy cantaloupe.

“Adaptation is a pre-eminent form of creation,” argues Madhavan, showing why Hutchinson deserves as much admiration as Fleming.

The “engineering practice of recombination” used by Hutchinson is both laudable and applicable beyond engineering. It helps make the most of available resources in any situation. But what is lacking are details. In his account of her ingenuity, we see why Madhavan’s book is both essential and inadequate. ■

Jonathon Keats’s book on Buckminster Fuller will be published by Oxford University Press in 2016

The image orchestra

Sonification technology is letting a blind photographer take holiday snaps with sound and even hear images of Pluto, says **Sandrine Ceurstemont**

IMAGINE taking photographs you can hear, thanks to sonification technology that translates the visual world into sound. Pranav Lal, a cybersecurity expert from New Delhi, India, was born blind and he's been using technology called the vOICe to take holiday snaps, most recently while trekking in the Himalayas.

The technology was designed to help people who are visually impaired navigate the world. But Lal frequently uses it for photography, where he picks out the most pleasant-sounding composition. "Scenes with varied elements sound interesting, for example, a bridge with lots of cables or a bright natural setting with streams and rocks," he says. "It's like an image orchestra."

The vOICe transmits an image from a camera to software that turns it into sound. In Lal's case, the camera part is a smartphone upgraded with a fish-eye lens and strapped to a headband.

After converting the image to greyscale, the software uses different characteristics of sound to represent visual features as it

"The brain begins to process the sound from the system in the visual cortex, treating it like an image"

pans across a scene from left to right. The position of an object is denoted by pitch – features higher up have a higher pitch – and brightness maps to loudness.

Lal admits that the complex shapes that inspire him can be a challenge to identify, but he can usually distinguish the foreground and background of an image by



The Himalayas as captured by Pranav Lal. Below: someone tries on the vOICe system Lal uses

The basics of the system are surprisingly easy to pick up, as Proulx demonstrated at last month's Latitude festival in Southwold, Suffolk, UK. After hearing the sonification of basic lines and shapes, a volunteer, who had his eyes covered, was able to read words just by listening to the corresponding sounds.

Later this year, a game version of the vOICe will be launched as a smartphone app to train people to use the system as well as to promote it. One of the most recent improvements allows the app to email photos. And the technology can also now be used with bone-conduction headphones, which don't cover the ears.

Although it is not essential for navigation – which was the original purpose of the vOICe – the system is able to identify colours. This has its uses: selecting which colours to sonify focuses on particular aspects of a scene. For instance, if you're shopping for red rather than green apples, you can change the setting to only hear the red ones, says Proulx.

Different cameras can also be hooked up to the device to boost human vision. For example, a thermal camera can replicate the vision of a snake through sound, or a night vision camera can help "see" in the dark.

Lal wants to delve into night photography during his travels, just as soon as he finds an affordable, portable night-vision camera. ■

separating the shapes in his head (see video at bit.ly/NSvOICe). Having used the system for a while, he can now create a mental image based on the soundscape he hears. But the result is different from the way he pictures shapes when feeling an object. "I've been told that it sounds like I am describing the negative of a photograph," he says.

As well as taking photos, Lal has used the system to see the first images of Pluto sent back from space last month. "I could make out mountains, but they were hazy," he says. "A patch on the right of the image was clearer as it was better lit."

The vOICe "rewires" the senses. After training, the brain begins to process the sound from the system in the visual cortex, treating it like an image.

Michael Proulx from the University of Bath, UK, worked

with blind people who use the system so he could investigate how visual parts of the brain can substitute input from other senses. In a recent study, he found that people using the vOICe can recognise blurry shapes as well as people with typical vision, even though computer vision systems struggle to identify such objects.



IMAGES COURTESY OF PRANAV LAL

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Special Instructions: Please submit the following materials through the ARIeS portal (<http://academicpositions.harvard.edu/postings/6320>). Applications must be submitted no later than October 15, 2015.

1. Cover letter
2. Curriculum Vitae
3. Teaching statement (describing teaching approach and philosophy)
4. Outline of future research plans
5. Names and contact information of 3-5 references (three letters of recommendation are required, and the application is complete only when all three letters have been submitted)
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Contact Information: Helen Schwickrath, Search Administrator, Department of Chemistry & Chemical Biology, Faculty of Arts and Sciences, Harvard University, 12 Oxford St., Cambridge, MA 02138. Phone: (617) 496-8190.

Contact Email: Helen@chemistry.harvard.edu



Faculty Positions in Biochemistry and Molecular Biophysics

The Department of Biochemistry and Molecular Biophysics at Washington University School of Medicine invites applications for several tenured/tenure-track faculty positions at the level of Assistant/Associate/Full Professor. Successful candidates will have established a strong record of research. Applicants seeking tenured positions must have a strong record of external funding.

Outstanding individuals working in any area of biochemistry and molecular biophysics are encouraged to apply. The candidate's research should be aimed at addressing fundamental questions related to molecular mechanisms of biological or biomedical relevance. Current research in the department spans a wide range of topics including computational biology, membrane proteins, molecular motors, nucleic acid / protein interactions, protein structure, enzymology and signal transduction. Additional information about the department is available at <http://www.biochem.wustl.edu>. Washington University has a highly interactive research environment with vigorous interdisciplinary graduate and medical scientist training programs.

Applicants should email their curriculum vitae, brief description of their research interests, and contact information of three individuals to the Search Committee at bmbsearch@biochem.wustl.edu. The committee will request letters from these individuals as necessary.

Completed applications will be reviewed on a rolling basis, starting immediately. For full consideration, applications should be received by December 1, 2015.

EOE/Minorities/Vets/Disabilities. The School of Medicine at Washington University is committed to finding solutions to global health problems, including ones that affect minority and disadvantaged populations.



ASSISTANT PROFESSOR in Complex Systems

The Center for the Study of Complex Systems (CSCS) at the University of Michigan invites applications for a tenure-track position of Assistant Professor of Complex Systems. Candidates at a more senior-level will also be considered. The appointment will begin **September 1, 2016**. This is a University-year appointment. Information about the Center can be found here: <http://www.lsa.umich.edu/cscs>.

Required Qualifications

Candidates must have a demonstrated research agenda focusing on complex systems. This may involve theoretical or applied research on complexity, including (but not limited to) mathematical and computational models in areas such as networks, computation, emergence, large events and robustness or applications where complexity lies at the core such as quantitative modeling of social systems, soft condensed matter physics, evolutionary or ecological dynamics, epidemiology and disease transmission, artificial life, neuroscience, and cognition. Preference will be given to candidates with a track record of working across disciplines.

How to Apply

All application materials must be uploaded onto this website:

<https://complexsystems-lsa.applicantstack.com/x/apply/a2guio5y9cxr>

The position is based in CSCS but will be a joint appointment with another department. In the cover letter, candidates should identify one or more partner departments at the University of Michigan suitable for such a joint appointment. Applicants must submit: a current CV, statement of current and future research plans, a statement of teaching philosophy and experience, evidence of teaching excellence (if any) and one writing sample. At least three letters of recommendation are required and must be uploaded onto the same website. Applications will be reviewed starting **October 1, 2015**. Applications will be accepted until the position is filled.

Women and minority candidates are encouraged to apply. The University of Michigan is an equal opportunity/affirmative action employer and is supportive of the needs of dual career couples.



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MANAGING DIRECTOR Center for Sustainable Nanotechnology PVL 83199

The Department of Chemistry of the University of Wisconsin-Madison is recruiting for a Managing Director in the Center for Sustainable Nanotechnology (CSN.) The Director works with the Center Director and the CSN Executive Committee and is responsible for actively directing and coordinating scientific research and additional integrative activities at multiple institutions to achieve the center's goals. A Ph.D. in Chemistry or related field experience is required. This is a full-time position with an anticipated beginning date of **October 1, 2015**. There will be a minimum twelve-month evaluation period.

Specific duties of the Director may include: Overseeing general operation of the center; establishing and implementing center-wide policies and procedures that will maximize the effectiveness of the center's scientific objectives and associated integrative activities; oversee center-wide finances (including multiple sub-contracts) and develop financial plans for the center; ensure that Center programs and activities are compliant with federal/state regulations; interface directly with federal agency personnel to meet reporting requirements and to communicate the center's scientific progress and objectives. This will include identifying high-impact scientific results and translating into language appropriate for program managers and policymakers.

For additional information, please go to:

http://www.ohr.wisc.edu/Weblisting/External/PVLSummary.aspx?pv1_num=83199

Additional information on the Center for Sustainable Nanotechnology is available at <http://susnano.chem.wisc.edu>

Please submit a letter of interest, curriculum vita and 3 references referring to **PVL 83199 to Dennis Reece at the Department of Chemistry, University of Wisconsin-Madison, 1101 University Ave., Madison, Wisconsin 53706-1322.**

To guarantee full consideration, all materials must be received by **September 15, 2015**.

The University of Wisconsin is an equal opportunity and affirmative action employer; applications from qualified women and minority candidates are encouraged. Unless confidentiality is requested in writing, information regarding the identity of the applicant must be released on request and there are deadlines for disclosure. Finalists cannot be guaranteed confidentiality. A background check may be required prior to employment



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This individual will be Director of the Biochemical Genetics Laboratory, and will also be responsible for teaching, research and/or clinical pursuits. Prior experience should include managing and interpreting biochemical lab results including standard biochemical testing and lysosomal disease screening and testing. Applicants with research interests will have demonstrated ability to conduct significant independent research, and a successful track record of grant funding.

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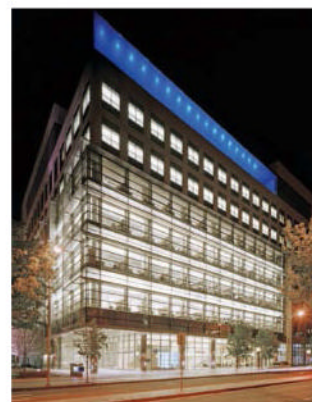
The University of Alabama at Birmingham offers an excellent benefits package including medical/dental insurance and dependent tuition. Interested applicants please send curriculum vitae including references, and a description of your teaching, clinical or research portfolio to:

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Professor and Chairman
c/o Dee Blakely-Stoudermire
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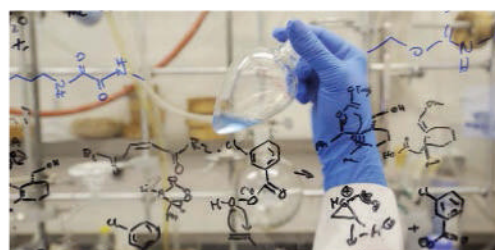


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Director, Division of Extramural Activities National Eye Institute



The National Eye Institute (NEI), a component of the National Institutes of Health (NIH) and the Department of Health and Human Services (DHHS), conducts and supports research, training, health information dissemination, and other programs with respect to blinding eye diseases, visual disorders, mechanisms of visual function, preservation of sight, and the special health problems and requirements of the blind.

Are you an experienced Scientific Administrator in search of an exciting career opportunity? We may be the right place for you. The NEI at the NIH is seeking an exceptional Scientific Administrator to serve as the Director, Division of Extramural Activities (DEA). The Director, DEA, reports to the Director, NEI and serves as the principal advisor on research administration policies including peer review, grants management and administrative management of the Division. The incumbent oversees several distinct but related functions involving the extramural operations and has full managerial and executive responsibility for the following activities: Providing leadership and advice on extramural research grant, contract, and training program operations and policies within NEI; Providing oversight of grants management activities and implementation of grants policies; Providing guidance at the interface of grants management and the NEI Budget Office; Providing oversight and direction for the peer review of research applications, training applications and contract proposals. The incumbent represents NEI on extramural research administration and policy committees both within and external to NIH and HHS; Provides executive and managerial oversight of policy development for extramural research grant and contract review and management procedures; Provides overall management of the operations of the National Advisory Eye Council (NAEC) and serves as its executive secretariat and managing the resources for the DEA, including financial and personnel needs.

The Director, DEA will have responsibility for the development, implementation and dissemination of extramural review and grants management policies and procedures both internal and external to the NEI. The incumbent serves as an authoritative source on NEI extramural research peer review regulations, and grants management policies, and maintains awareness of new developments in research administration through interactions at professional conferences.

QUALIFICATIONS REQUIRED: Candidates must have an M.D., Ph.D., or equivalent degree in a field relevant to the position and substantial leadership experience in managing a federally-funded extramural science program. This position will be filled under a Title 42(f) excepted service appointment.

SALARY/BENEFITS: The salary for this position will be commensurate with qualifications and professional experience. A recruitment or relocation bonus may be available, and relocation expenses may be paid. A full package of federal Civil Service benefits is available, including: retirement, health and life insurance, long term care insurance, leave, and a Thrift Savings Plan (401K equivalent).

HOW TO APPLY: Submit a current curriculum vitae, bibliography, and full contact details for three references. In addition, applicants are asked to prepare two statements: a vision statement and a statement that addresses the specific qualification requirements (please limit both statements to two pages each). Send application package to Yireiza Williams at ywilliams@nei.nih.gov by September 30.

NEI will begin accepting applications from August 25th through September 30th and plans to have the position open for at least 30 days, but will not close the applicant process until a candidate has been selected.

Information about NEI can be found at **NEI.NIH.GOV**

You may contact Yireiza Williams with questions and for more information about this vacancy at ywilliams@nei.nih.gov or on (301) 451-1936.

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The Gravity Gradiometer group is focused on researching and developing technology for delivery of an Airborne Gravity Gradiometer to provide geological information valuable for mineral exploration. The goal to achieve the target performance, which is more than an order of magnitude improvement over existing airborne instruments, presents challenges in many areas ranging from SQUID based superconducting transducers to advanced automation and control.

This position will be responsible for leading and coordinating the scientific and technical effort to drive down the noise under dynamic operation both on the flight simulator in the laboratory and in the field. Specifically the activities include operating, testing, evaluating, re-designing and re-building the instrument to achieve the required performance and reliability. There is a strong focus on maintaining accurate and relevant documentation of the process and outcomes of the work and producing technical reports.

The project is funded by Rio Tinto.

To be considered for this role, you will demonstrate:

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- *Extensive experience in the assembly and testing of high-precision instrumentation;*
- *A strong experimental understanding of superconducting physics and applications;*
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Assistant Professor of Chemistry

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Please apply to one search only. Applicants must upload a cover letter, a curriculum vitae with a list of publications, a succinct outline of research plans and a one page teaching statement. In addition, three reference letters are required. At the time of hire the successful candidate must have a Ph.D. in Chemistry or a related field. Joint appointments with other departments are possible. Review of applications will continue until all positions are filled.

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Call for Applications Chair,

Department of Medical Biophysics

The Schulich School of Medicine & Dentistry, at Western University, is inviting applications for the position of Chair in the Department of Medical Biophysics.

As Canada's first Department of Biophysics, the Department has grown to become one of Canada's leading centres for medical biophysics research with approximately 20 primary faculty members and over 70 actively collaborating cross appointed faculty leading internationally recognized research programs in medical imaging, microcirculation, computational modelling, biomechanics, and cancer. The department is the academic home to both undergraduate and graduate programs, including CAMPEP accreditation. It draws on a rich city-wide infrastructure incorporating two research Institutes, three hospitals, and five University Faculties. Research programs benefit from close collaborations between clinical and basic science faculty, with unique training programs in diverse fields.

The successful candidate should have a demonstrated track record of leadership and research and teaching excellence with a proven reputation for effective interpersonal and administrative skills. The new Chair will facilitate collaboration and be expected to support the research, educational and interdisciplinary initiatives of the Department. The successful candidate will build on the strength and forward momentum of the Department's graduate and undergraduate programs and promote the development of new initiatives in research, scholarship and education. He or she must have a PhD, MD, DDS or equivalent, and will receive a tenured academic appointment at the level of Associate or full Professor. Candidates with a research program complementing existing research strengths are particularly encouraged to apply. The position of Chair is for a five-year term, renewable.

Western University is located in London, Ontario, with a metropolitan census of 530,000. As Canada's 11th largest city, London boasts an extensive educational and health care community. With full time enrollment of 32,000, Western graduates students from a range of academic and professional programs. Further information about the Schulich School of Medicine & Dentistry and Western University can be found at www.schulich.uwo.ca, and <http://www.uwo.ca>. Western's Recruitment & Retention Office is available to assist in the transition of successful applications and their families. Details about the Department of Medical Biophysics can be found at <http://www.schulich.uwo.ca/biophysics/>.

Interested candidates should submit a CV outlining their research, teaching, and administrative experience and interests, including future directions, together with the names and addresses of three referees to:

Dr. Michael Strong, Dean
Schulich School of Medicine & Dentistry
Room 3701A, Clinical Skills Building
Western University
London, Ontario N6A 5C1
FAX: (519) 850-2357
selection.committee@schulich.uwo.ca

Please ensure that the form available at <http://www.uwo.ca/facultyrelations/faculty/Application-FullTime-Faculty-Position-Form.pdf> is completed and included in your application submission.

Applications will be accepted until the position is filled.
Review of applicants will begin after September 30, 2015.

Positions are subject to budget approval. Applicants should have fluent written and oral communication skills in English. All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority. Western University is committed to employment equity and diversity in the workplace and welcomes applications from all qualified individuals, including women and men, members of visible minorities, aboriginal persons, persons with disabilities, and persons of any sexual orientation or gender identity.



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Interested candidates should submit a cover letter that includes research interest/experience, curriculum vitae, and the names of three references to the attention of Gene P. Siegal, M.D., Ph.D., Robert W. Mowry Endowed Professor of Pathology, Director, Division of Anatomic Pathology, Department of Pathology, University of Alabama at Birmingham, path-aprecruits@mail.ad.uab.edu. All applications will be accepted until position is filled.

A pre-employment background investigation is performed on candidates selected for employment. In addition, physicians and other clinical faculty candidates who will be employed by the University of Alabama Health Services Foundation (UAHSF) or other UAB Medicine entities must successfully complete a pre-employment drug and nicotine screen to be hired.

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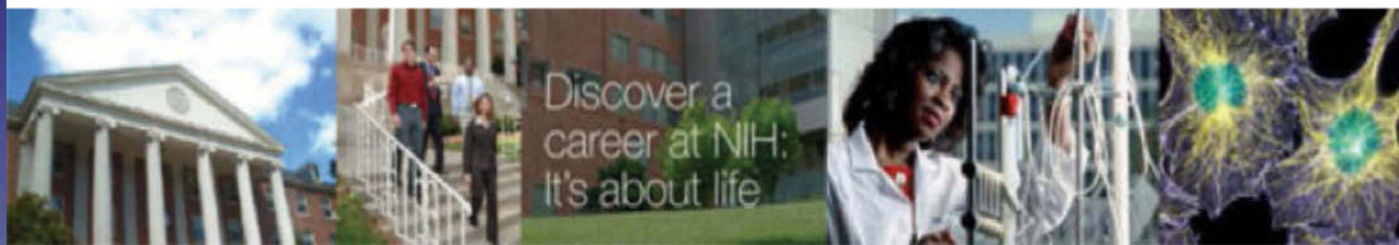
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AWIS

Director, Division of Extramural Science National Eye Institute



The National Eye Institute (NEI), a component of the National Institutes of Health (NIH) and the Department of Health and Human Services (DHHS), conducts and supports research, training, health information dissemination, and other programs with respect to blinding eye diseases, visual disorders, mechanisms of visual function, preservation of sight, and the special health problems and requirements of the blind.

Are you an experienced Scientific Researcher or Scientific Administrator in search of an exciting career opportunity? We may be the right place for you. The NEI at the NIH is seeking an exceptional Scientific Administrator to serve as the Director, Division of Extramural Science (DES). The incumbent plans and directs programs of research grants, cooperative agreements, individual and institutional research training awards, and research and development contract support for basic and applied clinical research and training as it relates to blinding eye diseases, visual disorders, mechanisms of visual function, preservation of sight, and the special health problems and needs of individuals who are partially-sighted or blind. The incumbent has responsibility for directing and managing multiple extramural scientific program initiatives and functions, managing the domestic and international extramural funding activities of NEI and providing policy direction. The incumbent advises the Director, NEI, regarding basic vision research activities, and coordinates with other NEI, NIH and DHHS organizations and the extramural community to accomplish Institute objectives. Additionally, the incumbent provides executive and managerial leadership in setting extramural scientific priorities of the Institute, making broad and significant decisions on scientific programs, developing Institute-wide policies and procedures, and determining resource allocation issues involving a major component of the Institute and a significant portion of NEI funding. Through his/her expertise and experience, the incumbent must be able to promote, manage, and oversee extramural research activities of national and international significance.

The incumbent serves as the principal advisor and liaison representing the DES and NEI on NIH work groups and committees pertaining to extramural science programs and activities and represents the Institute in interactions with the extramural community and at national and international conferences and seminars.

QUALIFICATIONS REQUIRED: Candidates must have an M.D., Ph.D., or equivalent degree in a field relevant to the position and substantial leadership experience in managing a federally-funded extramural science program. This position will be filled under a Title 42(f) excepted service appointment.

SALARY/BENEFITS: The salary for this position will be commensurate with qualifications and professional experience. A recruitment or relocation bonus may be available, and relocation expenses may be paid. A full package of federal Civil Service benefits is available, including: retirement, health and life insurance, long term care insurance, leave, and a Thrift Savings Plan (401K equivalent).

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Information about NEI can be found at **NEI.NIH.GOV**

You may contact Yireiza Williams with questions and for more information about this vacancy at **ywilliams@nei.nih.gov** or on (301) 451-1936.

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National Eye Institute (NEI)
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EDITOR'S PICK



Less a snowball, more of a slushball

From Birger Johansson

Richard Webb describes the most extreme version of a “snowball Earth” event, as proposed by Joseph Kirschvink (18 July, p 28). Others have suggested milder “slushball Earth” events. Since life apparently bounced back quickly after each event, it must have found some refugia.

Research by Adam Campbell at the University of Washington, Seattle, indicates that simple photosynthetic algae could have survived in a narrow body of water with characteristics similar to today's Red Sea. The “hard snowball” interpretation – with equatorial temperatures of -50°C lasting tens of millions of years – would rule that out. So where did life hide out? Hibernation fails on time scales beyond millennia. Crater lakes may be warm, but no single volcano survives that long. Very salty lakes might remain liquid but will kill everything except extremophiles. Even organisms living at sea floor hot vents need oxygen, dissolved at the liquid surface. Yet we exist.

I see three possible answers; divine intervention (Norse gods battling the Ice Giants), a Doctor Who (operation Noah's Tardis?) or... maybe science simply needs to look harder for evidence of milder “slushball Earth” events.

Umeå, Sweden

To read more letters, visit newscientist.com/letters

Is burning biomass such a good idea?

From Almuth Ernsting,
Co-director, Biofuelwatch

Fred Pearce describes the White Rose power station at Drax in Yorkshire as the “world's first power plant with negative emissions” (8 August, p 8). The Drax company is a master of political spin. In the last few months, it has managed to portray what would be the UK's first new coal power station since the 1970s as a climate solution that reduces carbon dioxide in the atmosphere. It positions the burning of millions of tonnes of wood pellets as “low carbon” despite overwhelming evidence that many of those pellets are sourced from clearing some of the world's most biodiverse subtropical forests.

To comply with UK planning policy and gain a £500 million (or potentially even £950 million) capital grant, White Rose must be built with the infrastructure for carbon capture and storage – but these guidelines don't require much, if any, carbon to be captured once the plant is operated. The oxy-fuel technology proposed is much cheaper and more energy-efficient to operate without CCS than with it.

The planning application for the power station states that at least 85 per cent of the fuel will be coal, not biomass. All this is happening while UK support for wind and solar power as well as home efficiency is being slashed.

Edinburgh, UK

From Scot Quaranda
Dogwood Alliance

Our forests are a vital carbon sink storing more than 10 per cent of US emissions annually. Instead of valuing our forests for this and all of the other important services they provide, such as clean drinking water, wildlife habitat, protection from storm surges and flooding, and as a place for

recreation, big utilities like Drax are pushing to chop them down and burn them for electricity, then call it great for the climate.

Asheville, North Carolina, US

Renewable energy is not taking over

From Andreas Rauch

Your interview with Malte Jansen of the Fraunhofer Institute for Wind Energy and Energy System Technology avoided important issues (25 July, p 17). Jansen says Germany is “doing a fairly good job of getting to the target of 80 per cent renewable electricity by 2050”, but the use of fossil fuels to generate electricity remains stable or increases slightly. Decreased nuclear power production is reflected by an overall decline in electricity generation and increased electricity imports.

Rosdorf, Germany

What will recharge the world?

From Nick Cook

When I saw your headline about “the battery that will recharge the world” I hoped for news of a revolutionary battery technology (25 July, p 20).

If we are to use batteries to support a power generation system based mainly on solar and wind renewable energy, then the cost of battery storage will probably need to come down to less than \$10 per kilowatt-hour – 100 times less than current cost.

In December 2010, there was a massive fall in wind power across Europe: output was just a few per cent of normal for a couple of weeks. Importantly this was also at a time when demand was near maximum and solar generation near minimum. To cover the UK shortfall alone in such a scenario would require more

than 500 times the amount of batteries produced globally, but only once every few years.

Cheltenham, Gloucestershire, UK

Whalers and killer whales teamed up

From Graham Stone

Your report on two dolphin species banding together is intriguing to say the least (25 July, p 6). It brings to mind an alliance that existed between two species many years ago on the south-east coast of Australia.

Back when whaling was a primitive and dangerous artisanal enterprise, orcas (killer whales) would herd larger species into Twofold Bay for the whalers to slaughter. All the orcas expected in return were the tongues from the killed whales.

This cooperation only existed between a particular pod of orcas and a particular human family. Rival whaling families tried to muscle in on the arrangement but without success.

Highett, Victoria, Australia

Cod's comeback isn't nearly enough

From Geoffrey Withington

It was welcome news to hear that cod is making a comeback in the North Sea and stocks on the northern Grand Banks are also picking up (11 July, p 6). While we should acknowledge the good work politicians have done so far, I'm afraid this is only the tip of the iceberg if we want healthy oceans.

Around 40 years ago, near Iceland and in the White and Barents seas, we were using nylon trawls that, if hopelessly snagged, were abandoned there. They were very expensive, so we didn't ditch them lightly. Now millions of tonnes of plastics and other garbage are dumped into the world's oceans. And is the public

“Reading about confirmation bias, fixation error, primal freeze and outcome bias”

Tom Watson MP tells his Twitter followers he's interested in why things fall apart (15 August, p 28).

aware that by-catch – unwanted marine life fetched up along with the saleable fish – includes dolphins, seals and turtles? Every politician on the planet needs to consider the health of the world's oceans. They have to live on the same planet as us mortals.

Bridge, Kent, UK

The benefits of 'born this way'

Although I regard myself to be a gay man, I do find some women attractive. And, as Lisa Diamond suggests is often the case (25 July, p 18), the types of women and men to whom I am drawn have changed (a little) over my 68 years. You might call this “fluidity”.

I take issue, however, with the argument that this means we should ditch the “born this way” line. My father has reluctantly come to accept that theory. He says, however, that if I cannot be heterosexual, I should be celibate. If people like him are told that my sexuality is “fluid”, then I fear

they would see it as proving that I could become heterosexual if I only tried hard enough.

“Born this way” may be simplistic, but I can see nuances in the “fluidity” argument being lost in societies that are determined to prove that homosexuals can be “converted”.
Name and address supplied

Responsibility and consciousness

From Anthony Castaldo
David Amodio discusses how unconscious bias can determine our actions in some situations (18 July, p 26). But I believe that every conscious thought is supported by hundreds or thousands of subconscious systems. If I type “insulation” when I meant to type “insolation”, I think the word “no” and correct it: but what neural structure triggered the word “no”? What structure beneath that knows my text is related to solar radiation and did a check in that context?

It is silly to speak about my subconscious as if my conscious mind is independent of it. I don't believe in conscious decisions; I believe that what we call a conscious decision is just an awareness that our myriad subconscious systems have collectively resolved a course of action or state of belief.

That does leave the possibility that one subsystem might hijack the whole and execute an action, such as shooting a child, that the collective of systems would reject if given time to reach a consensus. But the subsystem is not some alien: if it can seize control of a person then it is that person.
San Antonio, Texas, US

Doubts on E-cigs are not just puritan

From John Davies
As a doctor, I have spent time helping people to stop smoking, so I am delighted that Mike Taylor has been able to cut down with the aid of an e-cigarette (Letters,

8 August). But I disagree with his point that it is self-righteousness or puritanism that prevents medicine embracing the e-cig.

First, governments refuse to regulate the content of e-cigs, so we have no idea what they contain and in what quantities. Second, it takes a long time to carry out proper investigations into the health effects. Without that evidence, a doctor cannot advise their patient to use one – or not to.
Lancaster, UK

The editor writes:

■ Since we received this, Public Health England has concluded that e-cigarettes are less harmful than cigarettes and help most smokers to quit (bit.ly/NSe-cigsruling). But concerns about e-cigs reducing the stigma of smoking may remain (1 November 2014, p 35).

Tell me lies, tell me sweet little lies

From Jan Horton
Bruno Verschuere might consider whether the reason young adults lie more than other age groups (1 August, p 23) is because they are those most likely to be seeking sexual partners.
West Launceston, Tasmania, Australia

For the record

■ All in a haze? We meant to say that the sun breaks down methane in Pluto's atmosphere into fragments that then form hydrocarbon haze (1 August, p 5).

Letters should be sent to:
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110 High Holborn, London WC1V 6EU
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TOM GAULD

NEW SIGNS FOR THE SCIENCE PARK





PAUL McDEVITT

A HIDDEN gem is uncovered by Trevor Howland in the pages of *Crystal Energy*, a book that promises “150 ways to bring success, love, health and harmony into your life”.

As jaded cynics, we were tempted to think that crystal fruitloopery has no place in modern life, but turning to the chapter on business success proves us wrong. There we learn that, when placed on our desk, malachite “will soak up some of the electromagnetic pollution emitted by your computer”. Handy for those who can’t afford an EMPPad (22 August).

Even better, by circling the malachite around the computer twice daily, “its healing energy can be an added repellent to any new viruses that are attacking software programs”. Just remember to “cleanse the stone under running water” afterwards – preferably away from your computer, Feedback advises.

SOME of the other advice in *Crystal Energy* is more practical, if ominous. The chapter headed “Silencing noisy neighbours with white moonstone” recommends that if you have been driven to

your wits’ end by ceaseless clamour from next door, you should wait for a dark night with a waning moon, “which symbolizes natural endings” and perhaps unnatural ones too.

In the jet black of this night, grip a hunk of moonstone tightly in your fist like Macbeth with his dagger and “trust in the stone’s power”. Having done the deed, we are told, serenity will return to your home. Possibly followed by a police investigation.

PREVIOUSLY, Howard Bobry asked for Feedback’s help to find a phrase that means “this is so incredibly stupid that it’s difficult to respond”, after being told to trim the ends of his decking boards to overcome curling caused by moisture (8 August).

Marion Hanna writes to say that she also finds herself in need of such a phrase. “A local company here in Australia told me that they would not supply me with a solar-powered sun awning on a west-facing window,” she laments. The company’s rationale was that “there would not be enough sun on it to operate it in the winter”.

Many Britons would support a gull cull, “though that varied by age,” the BBC reports. “Half of respondents aged 18-24 opposed a bird cull, while the same number of over-60s backed one.”

IN HOWARD’S case, Steve Martin proposes replying to the manufacturer with an equally stupid suggestion. For example, Howard could recommend that “in the interest of public relations, the company trim the ends of all their decking presale”.

This strategy is not without its risks, as George Fisher illustrates when he recalls: “Some 70 years ago, I was trying to find the end of a ball of string without much success. My father suggested that someone may have cut it off.”

Finally, Christopher Jacob suggests describing incredibly stupid responses as “beyond wrong”, a term associated with Michael Shermer, who found ample opportunity to popularise the phrase as editor-in-chief of *Skeptic* magazine.

CONTINUING our litany of Truly Horrible Ideas for Saving the Planet (THISPs), Alex MacDonald lets fly with a feather-brained scheme.

“Seagulls are attracted into towns by the abundance of food waste, and leave behind white droppings,” mulls Alex. If seagull populations were boosted by suspending the collection of food waste, and their droppings allowed to accumulate “to a depth of several feet”, there would be enhanced reflection of solar energy from our towns and cities, he believes.

“There are minor issues with this proposal,” admits Alex: a massive population of aggressive seagulls, and the smell of the guano, “which some may find mildly unpleasant”.

However, he reckons that the climate engineering will be self-regulating and will confine itself to affluent areas – the principal contributors to climate change – because less affluent areas “do not exhibit the prodigious food waste upon which this proposal is founded”.

US patent 6,368,268 B1 is titled “Method and device for interactive virtual control of sexual aids using digital computer networks” – and that’s just what it covers. The idea was nothing new when the patent

application was filed in 1998, but a company called TZU Technologies is using it to sue small sex-toy start-ups for patent infringement.

Patent-infringement suits based on dubious claims are hardly new. But we are amused to see the matter-of-fact way in which the government bureaucracy deals with sex toys. Their elaborate classification scheme for tracking the subjects of patents buries such toys deep in “subclass” A61H for “physical therapy apparatus”, with US patent 6,368,268 B1 draped across several further sub-subclasses, from the descriptive “A61H19/44: Having substantially cylindrical shape” to the brusque “A61H2205/086: Buttocks”.

However, Feedback is chiefly pleased by the choice of parent class for this entire series, namely “A: Human necessities”.



SAGE advice from *The Telegraph* for those intent on watching the Perseid meteor shower and a fly-by of the International Space Station: “Amateur astrologists are urged to sit in a deckchair facing north-east.”

Perhaps the conjunction of the two events is an ominous portent, worries Ian Beaver, or then again, “maybe the journalist should be urged to sit in a deckchair facing well away from a typewriter”.

You can send stories to Feedback by email at feedback@newscientist.com. Please include your home address. This week’s and past Feedbacks can be seen on our website.

Radio gaga

A car radio needs an external aerial to stop the car itself interfering with the signal. Yet the fob on the car key also works by radio and is effective even if I hold it near the steel garage door with the car on the other side. So how does it work?

■ Metal is effectively opaque to all but the most energetic electromagnetic radiation, so most vehicles act as a Faraday cage, whereby the radiation is distributed around the exterior. However, some electromagnetic waves can pass through car windows – most notably visible light.

Remote keyless systems operate at a frequency of 433.92 megahertz in cars manufactured in Europe. This corresponds to a wavelength of about 0.7 metres, which means that the signal from a fob can pass through the windows to reach the transceiver inside.

But some wavelengths are simply too big to travel through the windows, and for these the car might as well be a solid metal box.

should be one-quarter of the signal's wavelength, but this is clearly impractical for many wavelengths.

*Mike Follows
Sutton Coldfield,
West Midlands, UK*

Everything but the curl

I've been making notes to revise for my exams, and as I write, the pages curl inwards first from the top corners of the paper, and then the bottom corners. Why is this? I'm using a black ballpoint pen on white A4 printer paper.

■ I suspect your note-writing is quite small and closely spaced, and that you apply more pressure than normal with the pen. This compresses the fibres of the paper and causes them to expand sideways, thus effectively stretching the paper below the pen. Because you don't write to the top, bottom and edges of the sheet, these parts remain unaffected and so curl up.

A classic example of this effect, but for a different reason, is a sandwich left out in the sun. Most people will notice that the corners and edges soon start to curl, and it will have become unpalatable. This time, the phenomenon is caused by the sides and upper surface of the bread drying out and shrinking.

The stretching effect caused by pressure is used by manufacturers to produce curved skin panels for

custom-built cars and aircraft.

A machine called an English wheel is used for this purpose. This consists of a rigid "G"-shaped frame supporting a large, flat wheel. Below this is a smaller wheel with a curved edge. A sheet of metal is fed between the wheels and worked back and forth.

In the hands of a skilled operator, quite complex shapes can be produced. There are many

"A sandwich left out in the sun will soon start to curl at the corners and edges, and become unpalatable"

videos online that show the machine in action. Before the invention of the English wheel, the stretch-shaping of metal was achieved with a hammer.

*Bob Halahan
Godalming, Surrey, UK*

This week's questions

DISEASE-PROOF

If you have a few drinks, does the alcohol in your bloodstream act as medication against any microbes in the body?

*Adam Wilson
Leigh-on-Sea, Essex, UK*

CATCH A FALLING STAR

How long would it take for all our space junk to fall back to earth and burn up in the atmosphere?

*Renee Colwell
New York City, US*

POLAR TRADER

If I bought 1000 tonnes of gold bullion in Antarctica and sold it in Mexico at the same price per kilogram, would I make a loss? Surely the consignment would be lighter at the equator than the poles because it is spinning faster?

*Richard Byrne
Swanmore, Hampshire, UK*

COLOUR WASH

My bath water is pale blue in Paris, but pale green in Berlin. What causes this? The pipes, water hardness or something else?

*Brian Smith
Berlin, Germany*

NIGHTHAWKS

The gulls where I live on the south coast of England can be heard squawking day and night. Why aren't they quiet, and presumably asleep, like other birds at night?

*Dawn McNally
Brighton, UK*

UNSUITABLE SUIT

I read that Neil Armstrong's spacesuit from his moon landing is deteriorating. It was, apparently, made out of materials created for only short-term use. Why was this and what are these materials? How can the suit be preserved? The spacesuit of another Apollo astronaut, David Scott, is on display in the Smithsonian National Air and Space Museum in Washington DC. This suit looks pretty much intact, so was it made of different materials?

*Alan Brewer
Washington DC, US*

"Some radio wavelengths are simply too big to pass through car windows, hence car aerials"

FM radio signals can be as short as about 3 metres, but AM signals range from more than 100 metres to half a kilometre. This is why cars are fitted with external aerials. Ideally, their length

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